# NCCS Visualization Workflow Tutorial

NCCS USERS MEETING

**Jamison Daniel , Scientific Computing**

**March 28, 2007**

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This document:

- 2007_NCCS_VIS_TUTORIAL.pdf
    - http://users.nccs.gov/~d65/2007_VIS_TUTORIAL.pdf

Data Files Used In This Tutorial

- f14.011.cam2.h0.1900-02.nc
    - http://users.nccs.gov/~d65/ f14.011.cam2.h0.1900-02.nc
- blue_marble.png
    - http://users.nccs.gov/~d65/ blue_marble.png

Software Used In This Tutorial

- VisIt 1.5.5
    - http://www.llnl.gov/visit
- ncBrowse 1.6.3
    - http://www.epic.noaa.gov/java/ncBrowse
- NetCDF 3.6.1
    - http://www.unidata.ucar.edu/software/netcdf

## Tutorial Introduction and Motivation

This tutorial attempts to demonstrate an introductory representation of a scientific visualization workflow. All software used in this tutorial is open source and is both available and supported at the National Center for Computational Sciences (NCCS). The software described in this tutorial can be obtained from the respective websites and is available for Linux, WIN32, and MacOS. The hardware requirements for this tutorial have been limited to include most laptop and desktop machines.

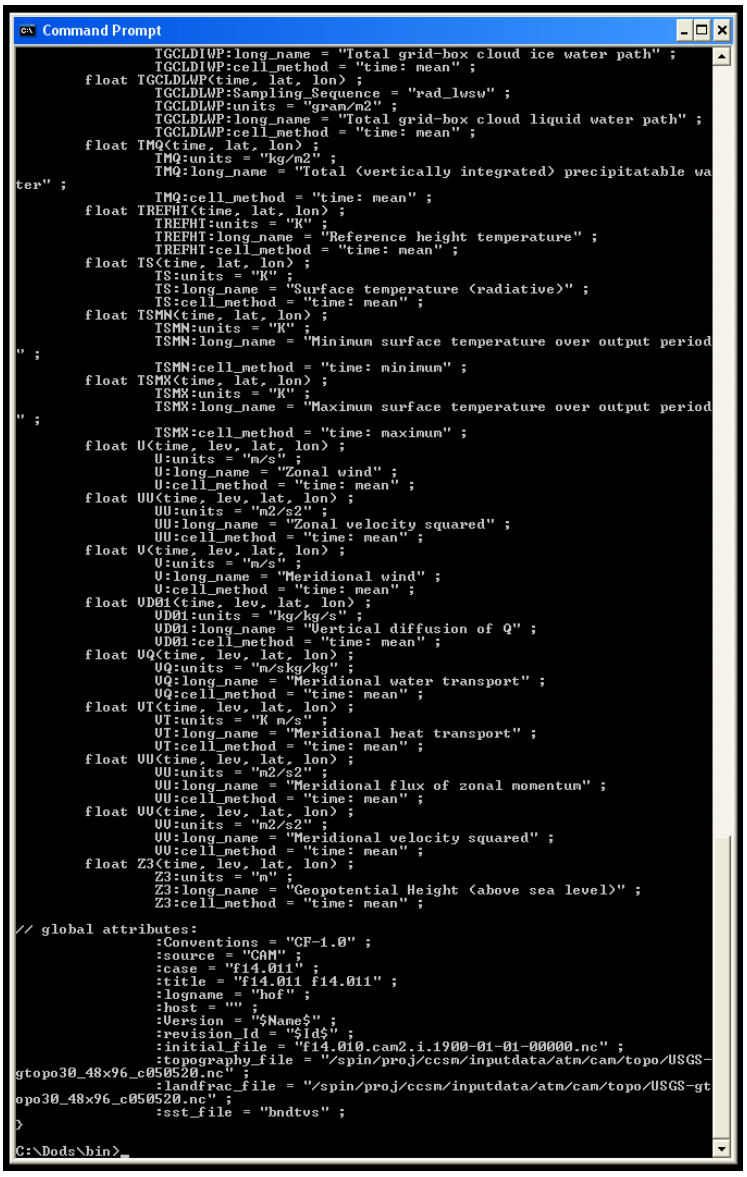
This tutorial involves a preliminary climate dataset from the Community Climate System Model (CCSM) simulations performed on the Cray X1E at the NCCS. Scientists are interested in carbon assimilation via photosynthesis and the return of carbon dioxide to the atmosphere via microbial respiration. This tutorial will outline the steps required to create a visualization illustrating the product of the net ecosystem exchange near the Amazon Basin, the Congo, and Eastern Europe and the $CO_2$ flux due to the respiration of vegetation and soil microbes, sometimes referred to as "green $CO_2$".

A First Look At The Data

It is often useful to use low-level lightweight visualization tools to obtain a quick preliminary understanding the data.

At the lowest level, the ubiquitous *ncdump* is installed as a part of the netCDF library. Ncdump simply generates an ASCII representation of a specified netCDF file on standard output. Ncdump may also be used as a simple browser for netCDF data files, to display the dimension names and sizes; variable names, types, and shapes; attribute names and values.

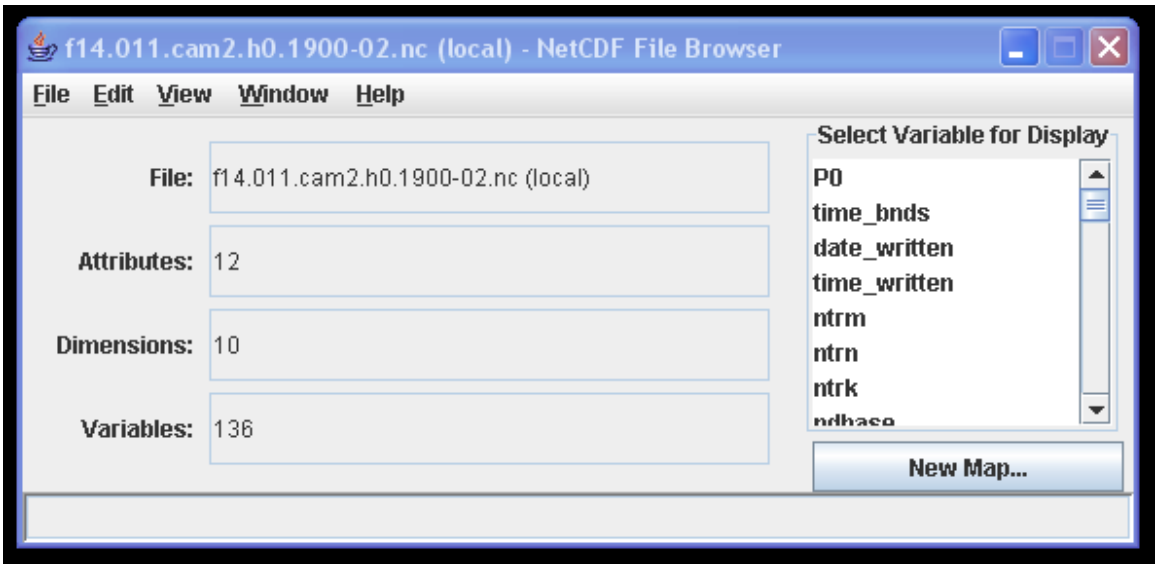
While often useful, browsing data files with ASCII text is not an effective visualization tool.



For quick visual representations of the data, a more appropriate lightweight tool is ncBrowse. NcBrowse is a Java application that provides interactive graphical displays of data and attributes from a wide range of netCDF data file conventions. Comprehensive help for ncBrowse can be found online at
http://www.epic.noaa.gov/java/ncBrowse/terminology-index.htm

1. Start ncBrowse.

2. Left-click on File->Open File (or hotkey Ctrl-O) and navigate to the f14.011.cam2.h0.1900-02.nc netCDF data file to open it.




1. Click View->As Tree…

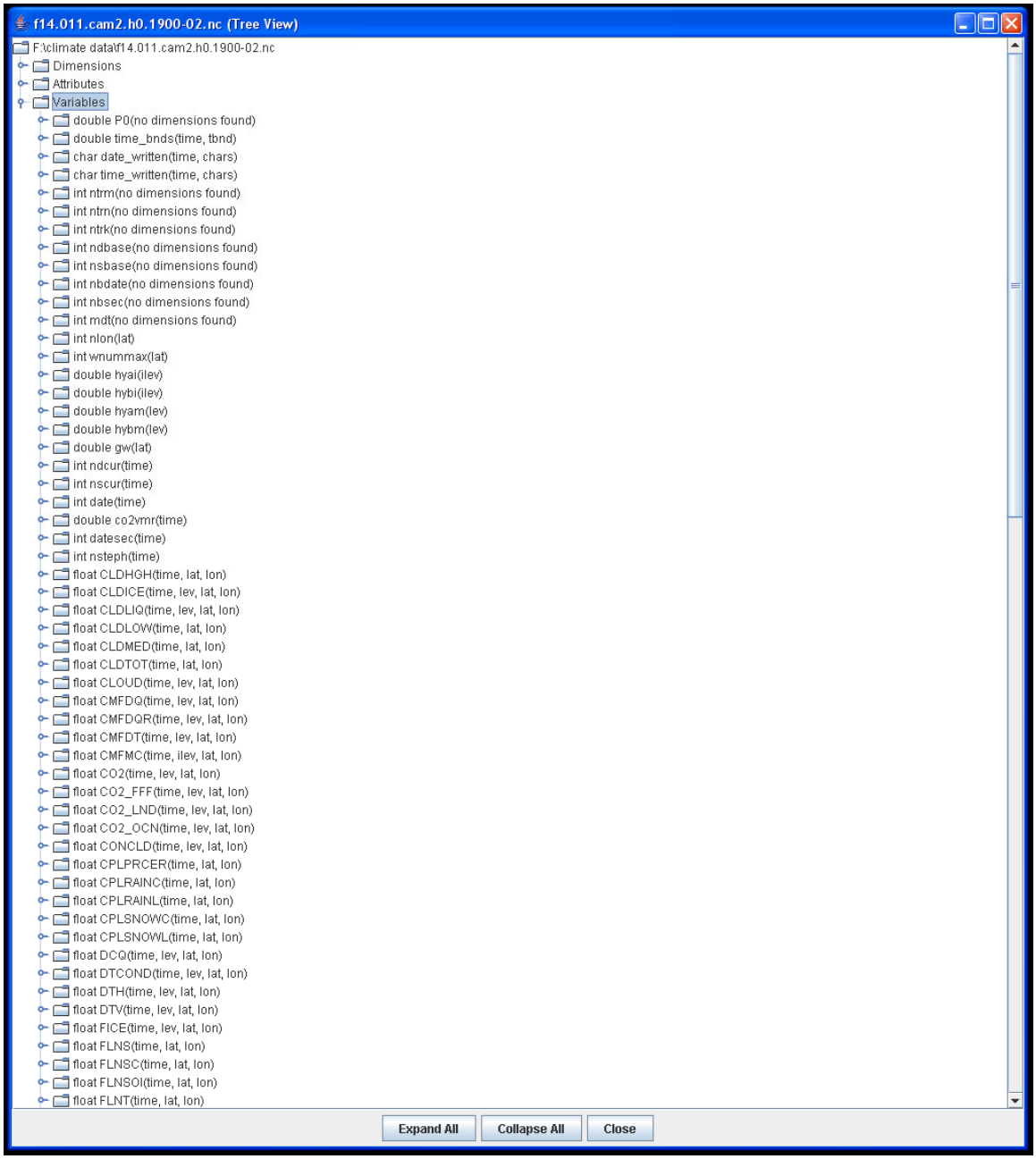
2. A new window should appear showing a tree view of the Dimensions, Attributes, and Variables. Click the "Expand All" button at the bottom of this new window.

3. Observe the Dimension tree. Observe that the data is represented using 48 grid points latitude north and 96 grid points longitude east. Also observe that we have 36 levels where positive values represent "down". This is counter intuitive to many people that are familiar with positive values representing an increase in altitude.


f14.011.cam2.h0.1900-02.nc (Tree View)
F:\climate data\f14.011.cam2.h0.1900-02.nc
Dimensions
lat = 48
long_name = "latitude"
units = "degrees_north"
lon = 96
long_name = "longitude"
units = "degrees_east"
lev = 26
long_name = "hybrid level at midpoints (1000*(A+B))"
units = "level"
positive = "down"
standard_name = "atmosphere_hybrid_sigma_pressure_coordinate"
formula_terms = "a: hyam b: hybm p0: P0 ps: PS"
ilev = 27
long_name = "hybrid level at interfaces (1000*(A+B))"
units = "level"
positive = "down"
standard_name = "atmosphere_hybrid_sigma_pressure_coordinate"
formula_terms = "a: hyai b: hybi p0: P0 ps: PS"
isccp_prs = 7
long_name = "Mean ISCCP pressure"
units = "mb"
isccp_prs_bnds
isccp_prs_bnds[0] = 0.0
isccp_prs_bnds[1] = 180.0
isccp_prs_bnds[2] = 310.0
isccp_prs_bnds[3] = 440.0
isccp_prs_bnds[4] = 560.0
isccp_prs_bnds[5] = 680.0
isccp_prs_bnds[6] = 800.0
isccp_prs_bnds[7] = 1000.0
isccp_tau = 7
long_name = "Mean ISCCP optical depth"
units = "unitless"
isccp_tau_bnds
isccp_tau_bnds[0] = 0.0
isccp_tau_bnds[1] = 0.3
isccp_tau_bnds[2] = 1.3
isccp_tau_bnds[3] = 3.6
isccp_tau_bnds[4] = 9.4
isccp_tau_bnds[5] = 23.0
isccp_tau_bnds[6] = 60.0
isccp_tau_bnds[7] = 379.0
isccp_prstau = 49
long_name = "Mean pressure (mb).mean optical depth (unitless)/1000"
units = "mixed"
time = UNLIMITED (1 currently)
long_name = "time"
units = "days since 1900-01-01 00:00:00"
calendar = "noleap"
bounds = "time_bnds"
tbnd = 2
chars = 8
Attributes
Variables
Expand All
Collapse All
Close

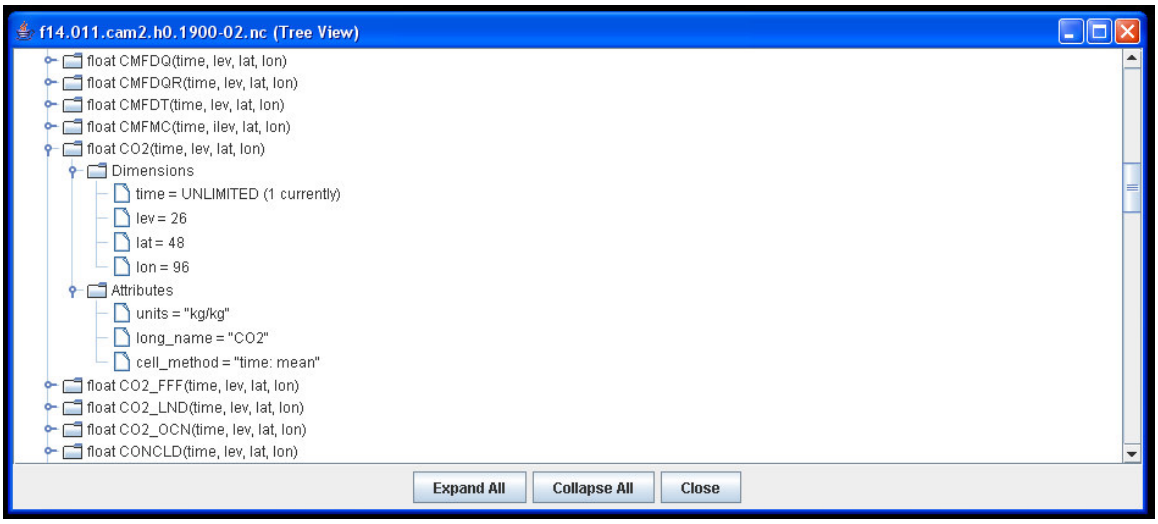
1. Collapse the Dimension and Attribute trees by left-clicking on the twirly icon to the left of the text and file folder icon.

2. Expand and collapse the Variables tree so that we can see each variable branch. This tree-view offers a concise summary of variable data size and dimensions.



1. We are interested in visualizing $CO_2$ formations over land, so scroll down to the CO2_LND variable and expand the variable.

2. Observe that the data is stored as floats and is on a 96x48x26 grid.



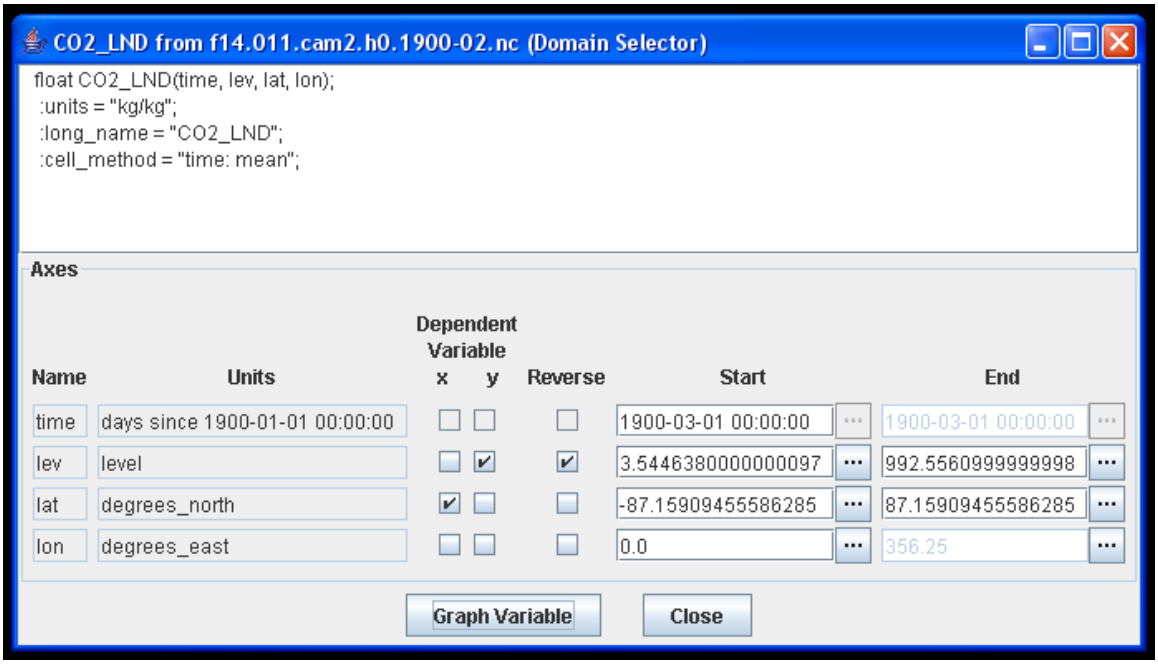

1. Close the tree-view window.

2. Scroll down in the "Select Variable for Display" window and double left-click on the CO2_LND variable. This will open a new "Domain Selector" window.

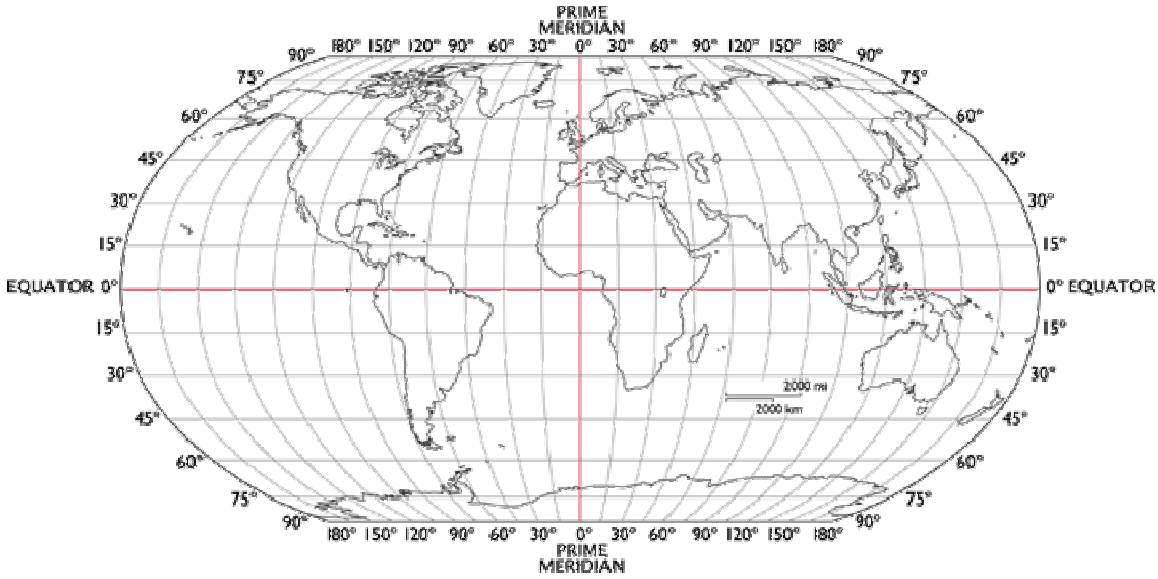
3. Observe that the latitudinal degrees north range from -87.16 to 87.16 and the longitudinal degrees east range from 0.0 to 356.25.

4. Remember that larger values of lev correspond to decreased altitude. This is counterintuitive, so check the Reverse radio box in the lev row. Now positive values of lev will represent higher altitudes.

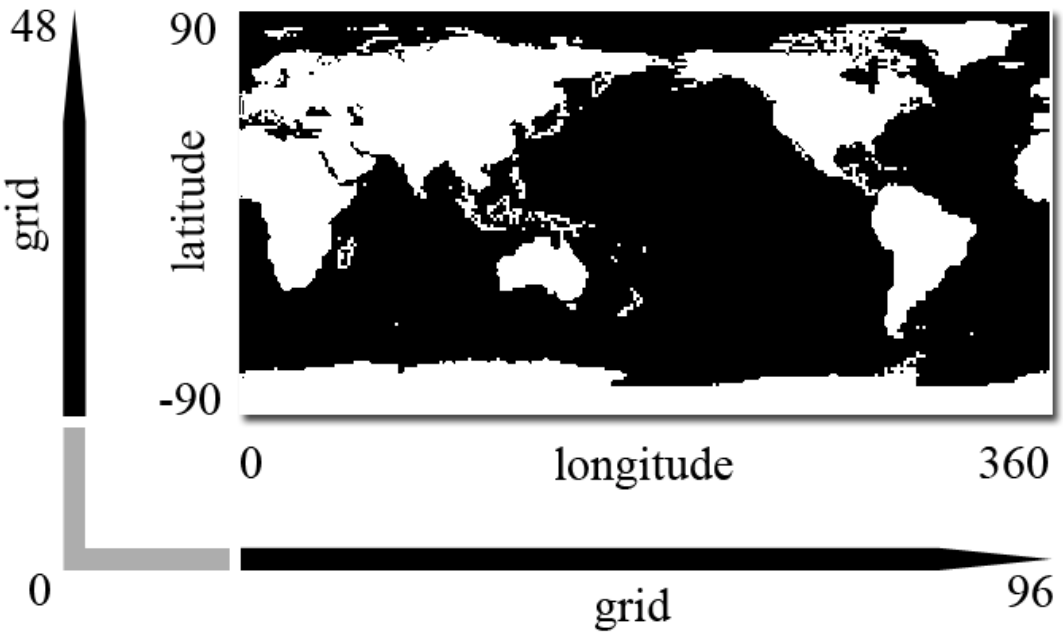
5. We traditionally represent height on the y axis, so click the 'y' radio box under Dependent Variable in the level (lev) row. The 'x' radio box for latitude should automatically update to reflect the necessary changes.




Latitude (horizontal lines) is the angular distance, in degrees, minutes, and seconds of a point north or south of the Equator. Lines of latitude are often referred to as parallels. Longitude (vertical lines) is the angular distance, in degrees, minutes, and seconds, of a point east or west of the Prime (Greenwich) Meridian. Lines of longitude are often referred to as meridians.



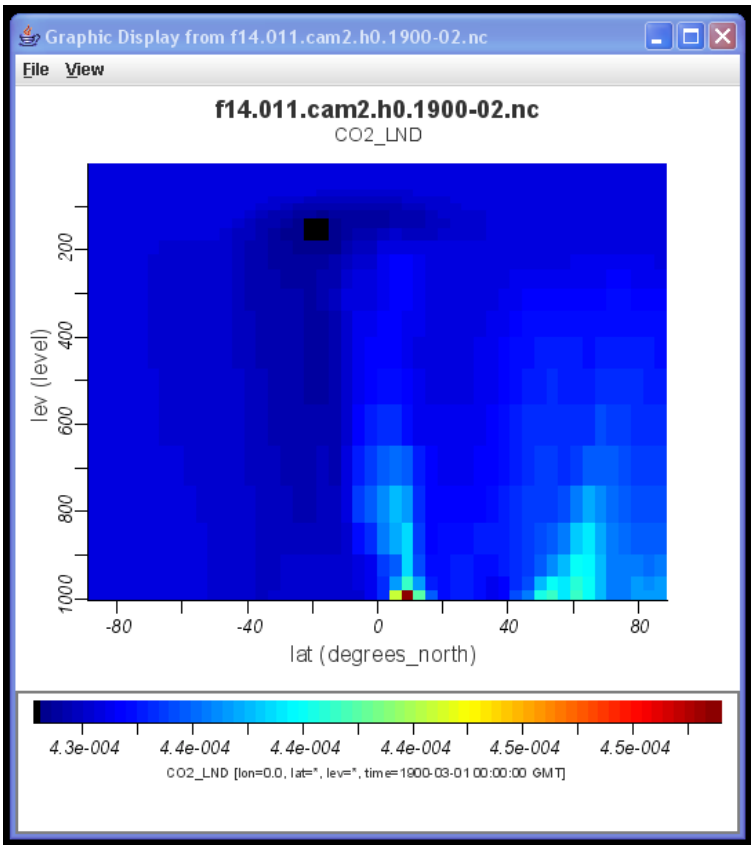
The following graphic represents the latitudinal and longitudinal grid mapping observations made thus far in the tutorial.



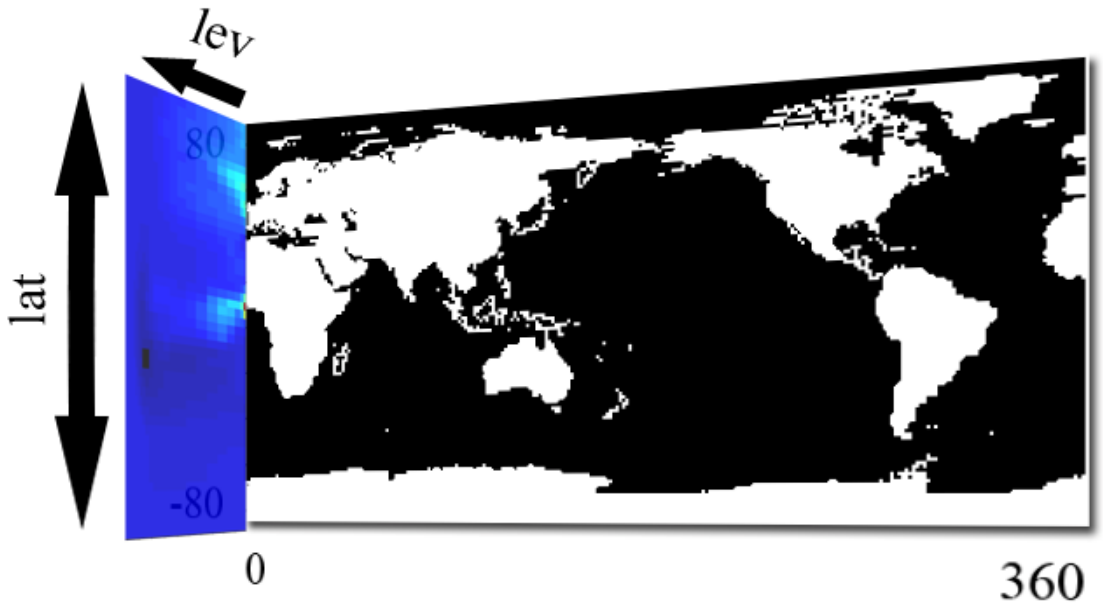

1. Observe that the y-axis is set to level and the x-axis is set to latitude. It is possible to adjust the Start and End scope of these axes, but leave the values at the default. Observe that we can only change the start of longitude since this represents the cutting plane location only.

2. Click the Graph Variable button at the bottom of the *Domain Selector* window.

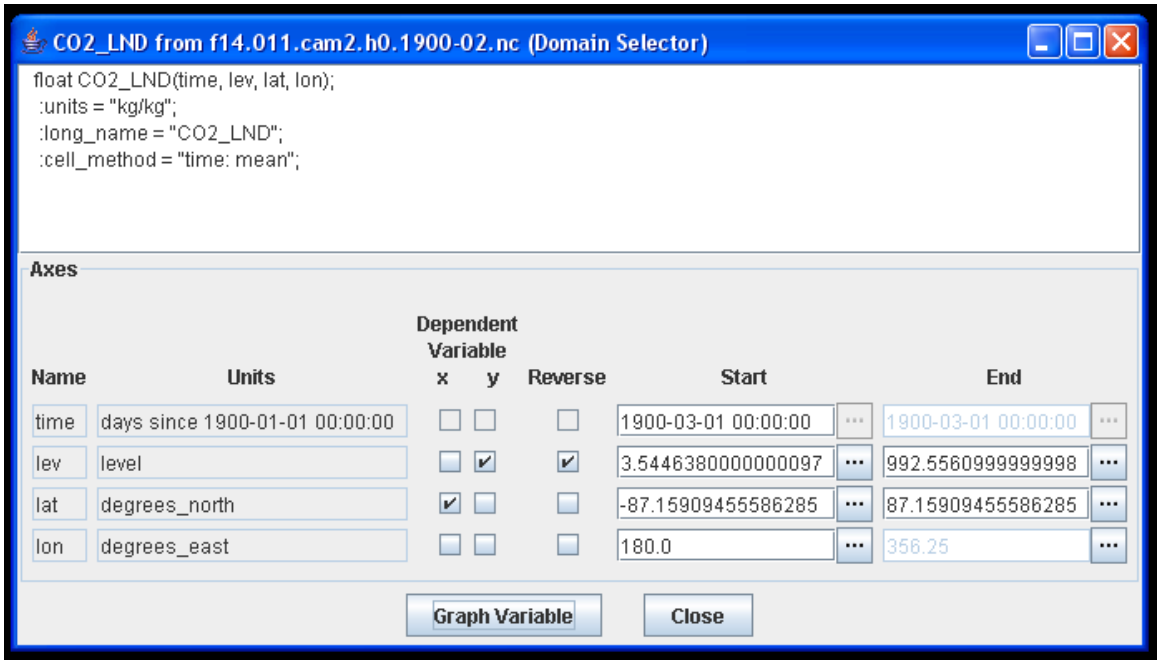
3. A new Graphic Display window will appear. Observe a possible plume forming over land at -20 degrees latitude.



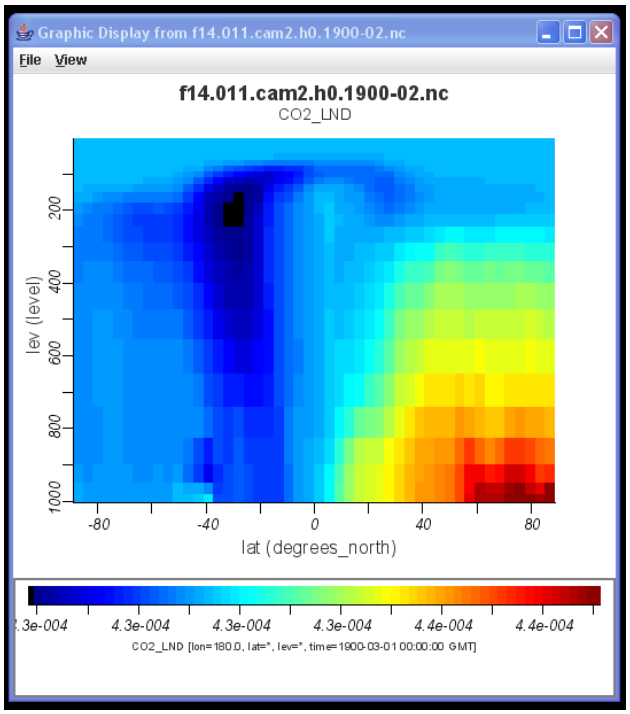

We are visualizing a pseudo-color cut-plane at 0 degrees longitude. The graphic below represents how this cut-plane corresponds to the overall volume.



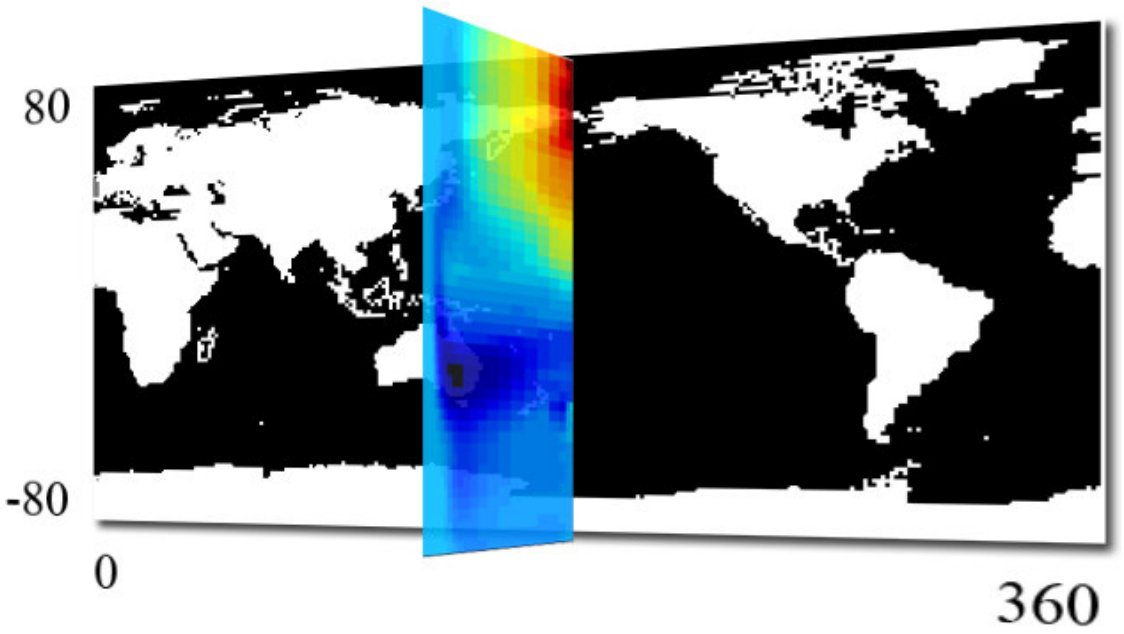
1. Change the longitude value to 180.0 by typing 180.0 into the Start text box in the longitude row.




2. Click on the Graph Variable button. Observe the resulting Graphic Display window.



We have now moved the cut-plane to the center of the data grid as illustrated in the following graphic.

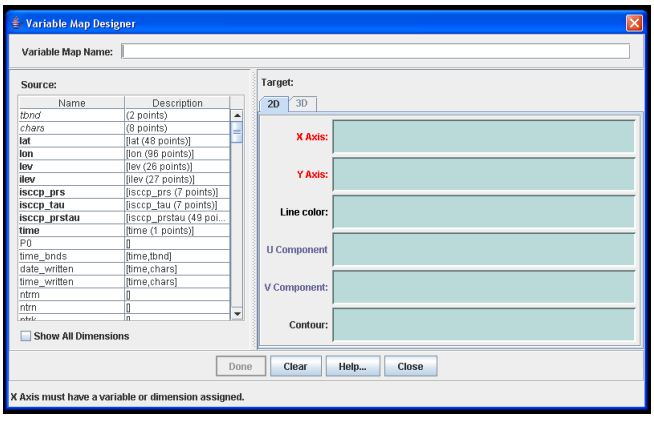



We now want to animate the cut-plane through the volume without having to type in each plane coordinate.

1. Return to the main *NetCDF File Browser* window, closing any child windows that we have opened so far.

2. Highlight the CO2_LND variable name in the "Select Variable For Display" window by left-clicking the text.

3. Now, click on the "New Map…" button below the "Select Variable For Display" window. The *Variable Map Designer* window will open.



1. A map is designed by dragging sources from the left to the target on the right. Left-click-and-hold on the "lat" variable listed in Source window. Drag and drop it into the blank box labeled X Axis in the Target window.

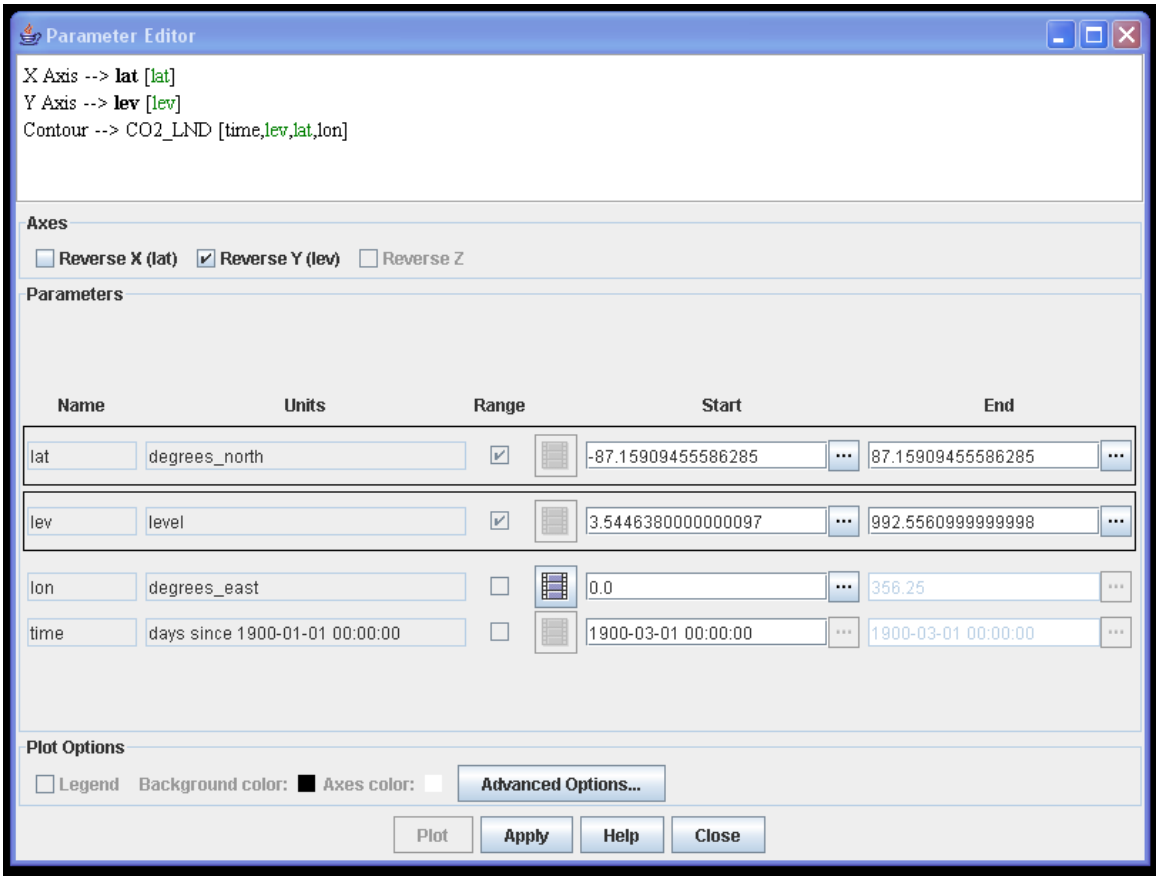
2. Drag and drop the "lev" variable to the Y Axis Target window.

3. Scroll down in the Source window and find the CO2_LND variable. Drag and drop this variable into the Contour Target window.

4. In the "Variable Map Name" text box at the top of the *Variable Map Designer* window type "CO2_LND Contour Animation".

5. Click the "Done" button at the bottom of the window to save the new map. This will close the Variable Map Designer window.

6. Now focus once again on the main "NetCDF Browser window. Use the scrollbar to scroll to the bottom of the "Select Variable For Display" list. You will see a new listing in blue called "CO2_LND Contour Plot". Double-left-click this item. A new Parameter Editor window will appear.

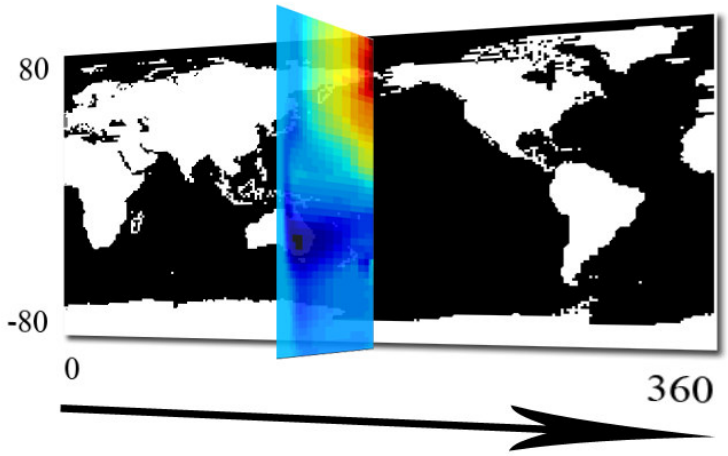


7. Left-click the radio box labeled “Reverse Y (lev)” in the “axes” section to add a checkmark. The positive y values will now correspond to increased altitude.

8. Now left-click the Plot button at the bottom of the Parameter Editor window. This will create a new window labeled CO2_LND Contour Animation that looks similar to what we have seen previously in this tutorial.

9. Observe that back in the *Parameter Editor* window an icon that was grayed out and unavailable before we opened the plot window. The icon is in the “lon” row and looks like a movie film strip. Click on this movie strip icon to open the Animation Controller window.


10. Click the Play icon (third button from the right) to begin the animation. The CO2_LND Contour Animation window will display the cut-plane animation. Drag the speed slider to the right of the window to increase the speed of the animation.

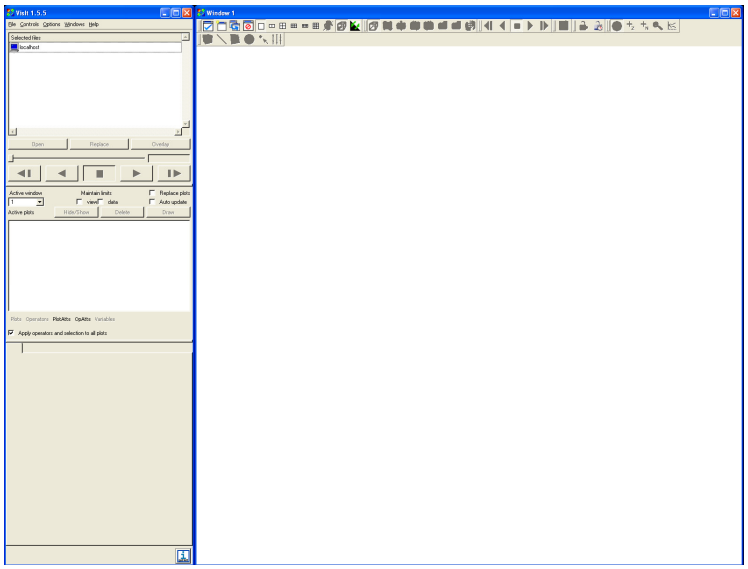



Animating cutplane along meridians.

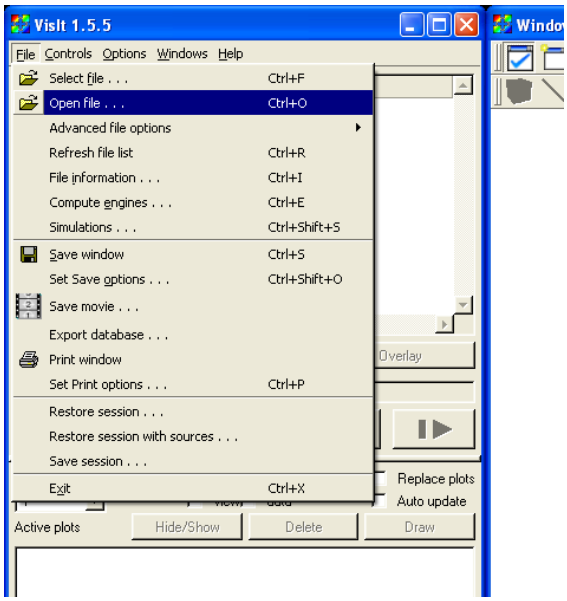
A Detailed Look At The Data

A more detailed visualization of the dataset, using techniques that our lightweight visualization tools do not support, is often desirable. For this tutorial, the VisIt visualization software will be used. The Visit software and documentation can be downloaded at www.llnl.gov/visit. This tutorial assumes the default configurations settings in VisIt after a fresh install.

1. Start VisIt. You will see a screen similar to the one below.



2. We first need to open our datafile. Left-click on "File" option at the top left of the menu bar and then left-click on "Open File" (File->Open File).

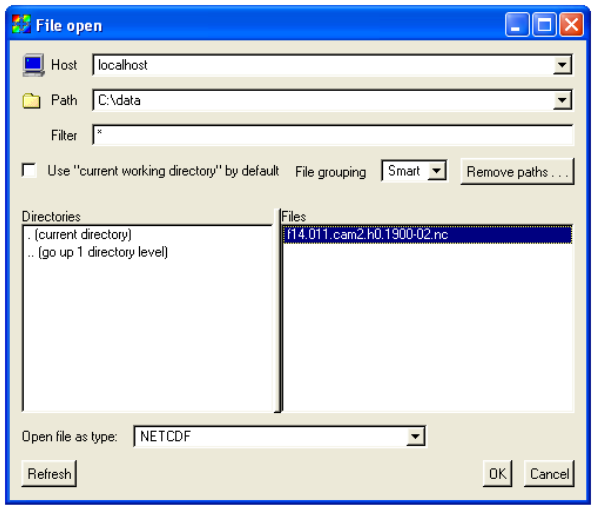


3. Navigate to your data file and left-click it to highlight the filename.

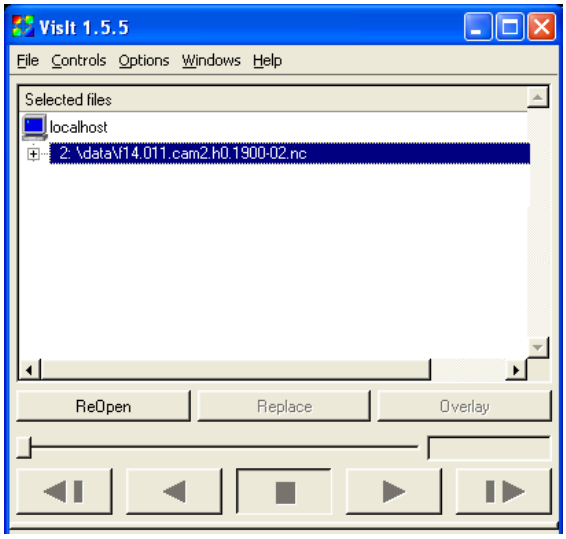
4. Select the NETCDF file type in the “Open file as type” drop down menu.

5. Click the OK button at the lower right hand corner of the “File open” window.

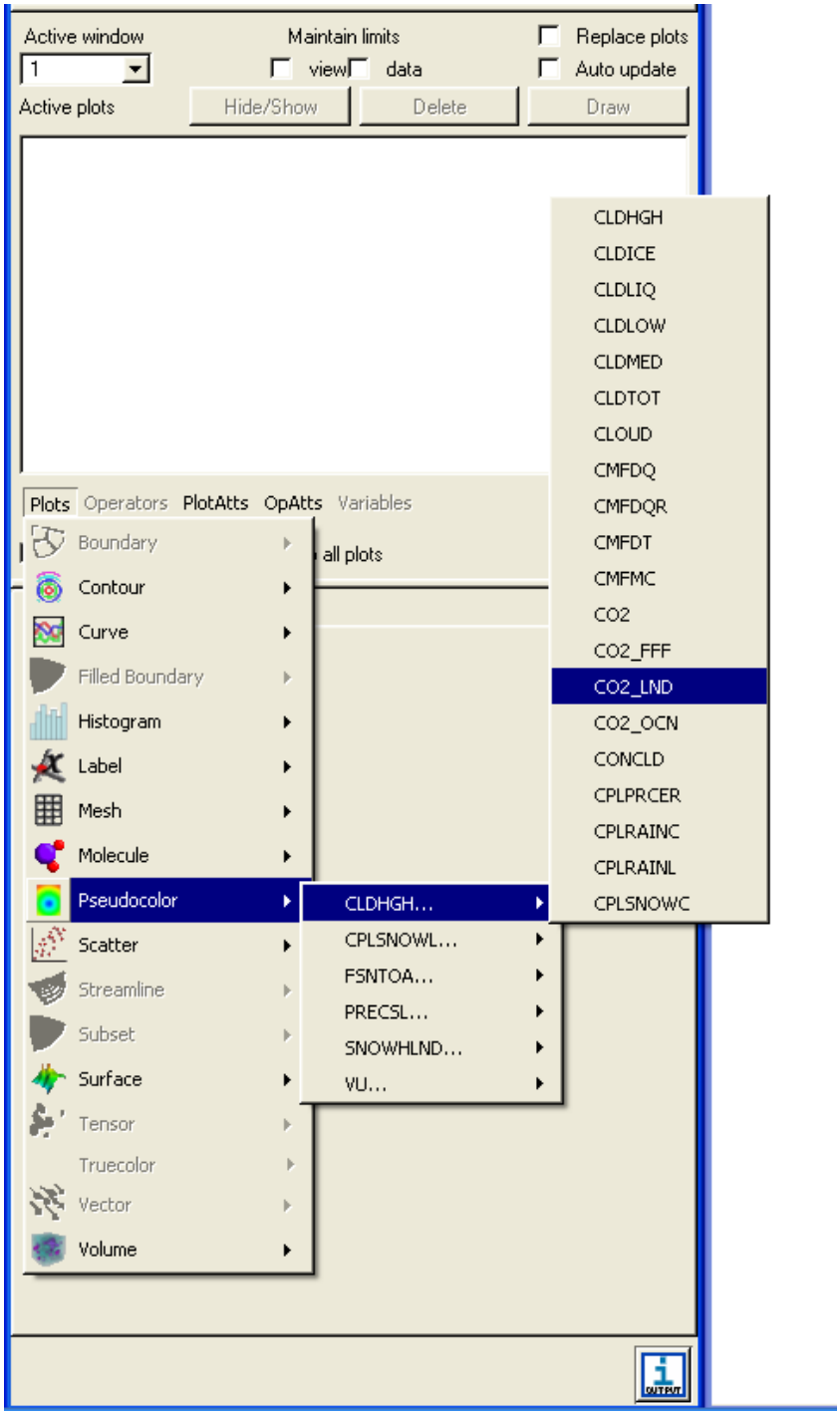
   NOTE ON VISIT 1.5.5*: VisIt 1.5.5 has a minor NetCDF bug that will occasionally cause a warning message to appear. In the context of this tutorial, the message may read, “The compute engine running on host issued the following warning:* In domain 0, your nodal variable “CO2_LND” has 11501568 values, but it should have 119808. Some values were removed to ensure VisIt runs smoothly. *This bug has been patched and will not appear in the 1.6 release of VisIt. For the purposes of this tutorial, this dialog can simply be dismissed.*



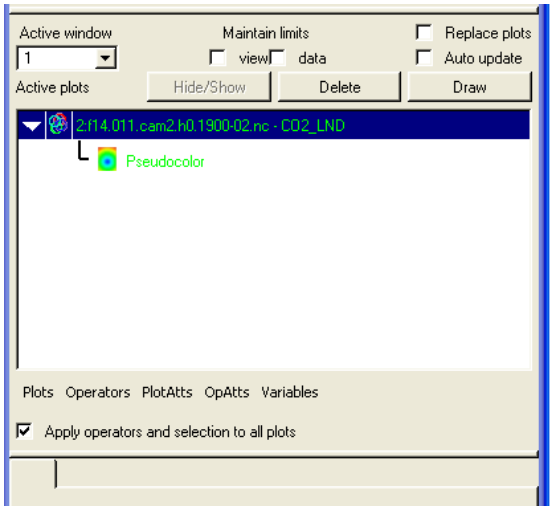

1. Observe the f14.001.cam2 datafile is highlighted in the *Selected files* window. Notice that the Open button has been replaced with the ReOpen button.



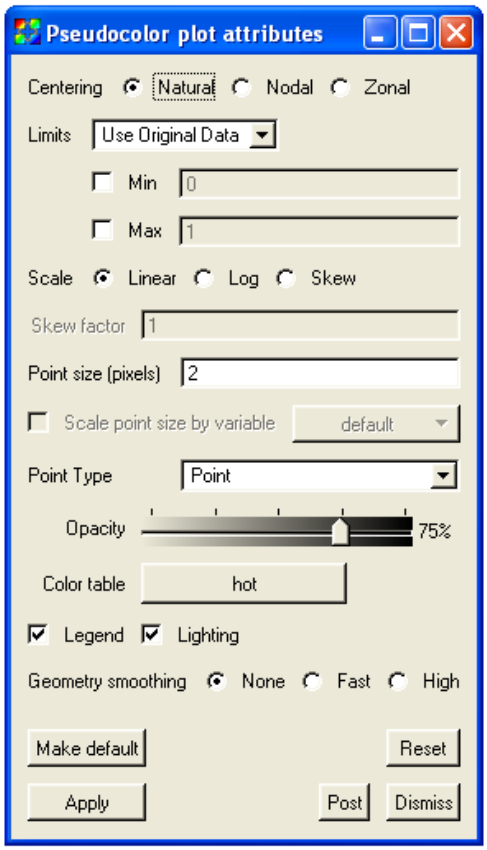
2. Observe the active plotting section of the VisIt interface. Left-click on “Plot” on the menu bar to display the pull down menu. Hover the mouse cursor over “Pseudocolor” to reveal the available variables. Hover the mouse cursor over “CLDHGH” to reveal the next level of variables. Now left-click CO2_LND.



1. Observe the CO2_LND variable and filename listed in green in the active plots window. Click on the twirly to the left of the filename to expand the tree. Observe that the Pseudocolor plot is listed as a branch under our variable name.

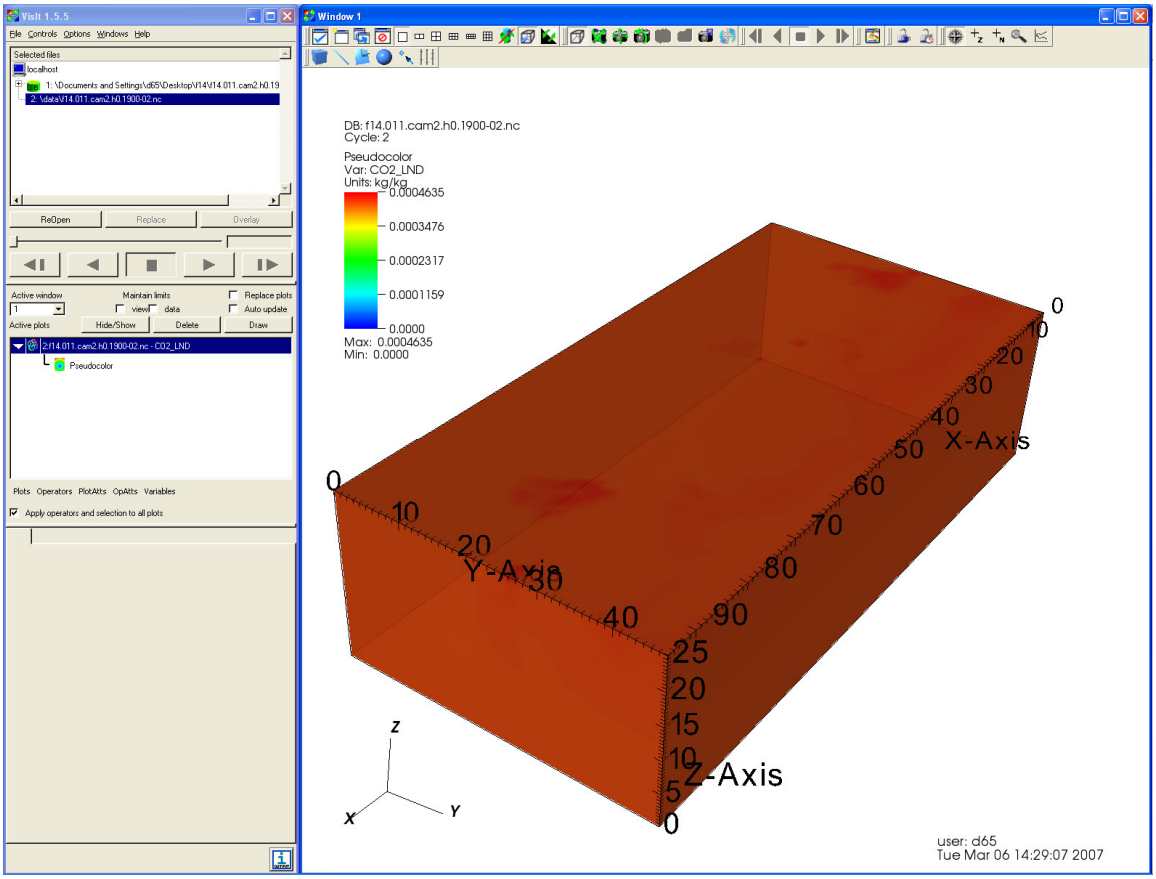



2. Double-left-click on the Pseudocolor branch to see its properties. A new Pseudocolor plot attribute will appear.



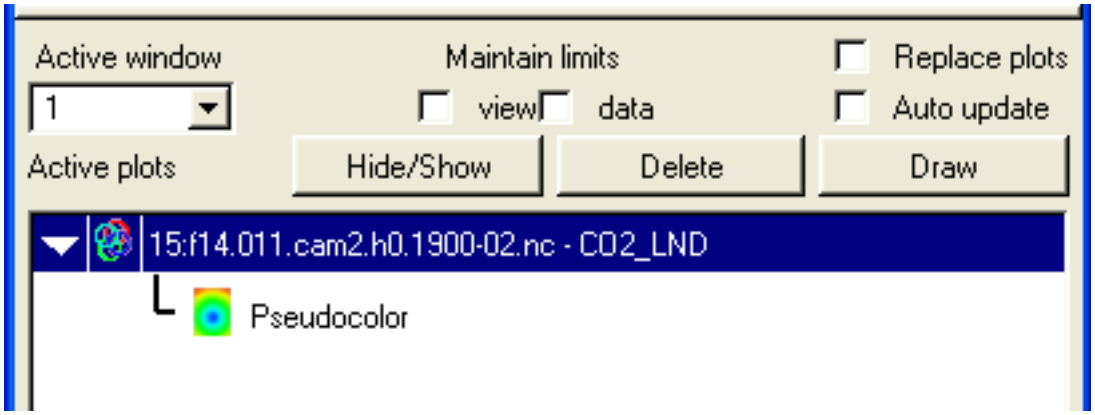
3. Move the Opacity slider down to 75% by left-clicking-and-hold on the slider triangle and moving the mouse to the left.

4. Click the Apply button and then click the Dismiss button.

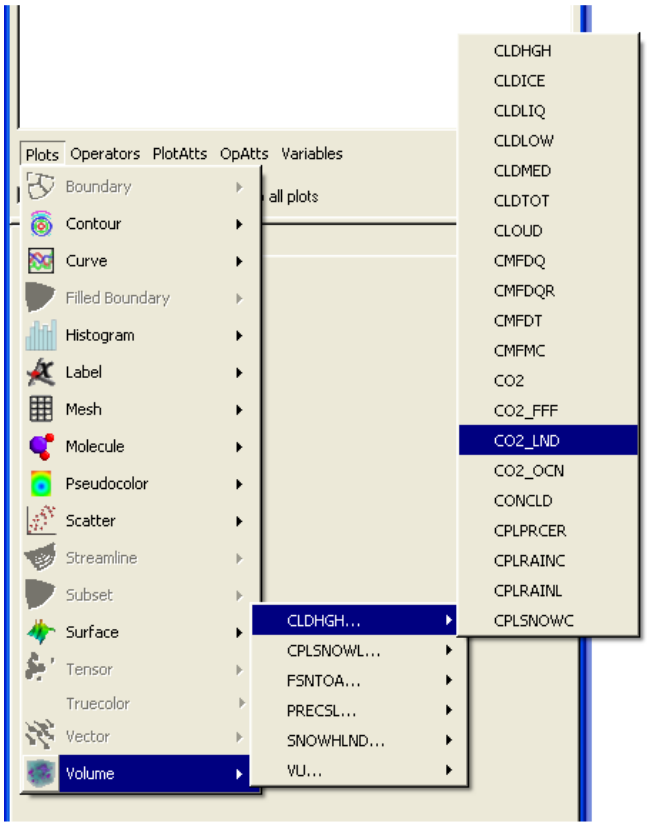



5. The entire volume of CO2_LND is now visible. Left-click-and-hold on the rendering window. Move the mouse around to manipulate the camera view. Middle-click-and-hold on the rendering window. Move the mouse up and down to zoom in and out.

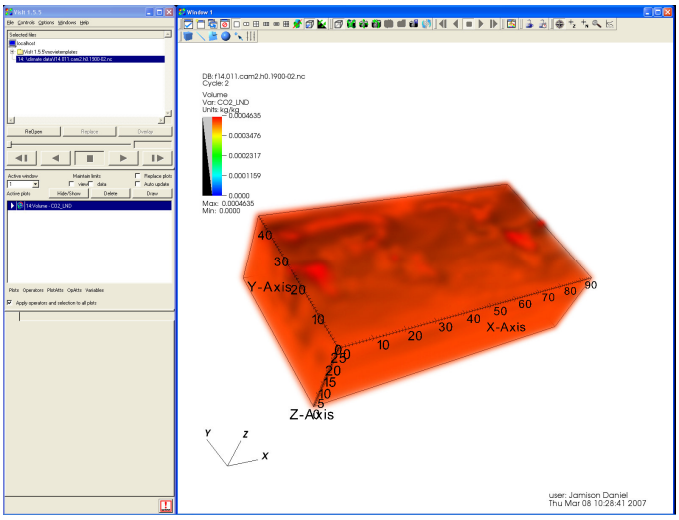
1. Our pseudocolor plot does not illustrate the information we seek. Delete the pseudocolor plot by first left-clicking on the name of the variable in the Active Plots list and clicking the Delete button. Alternatively, you could click the Hide button if you wish to use the plot again.



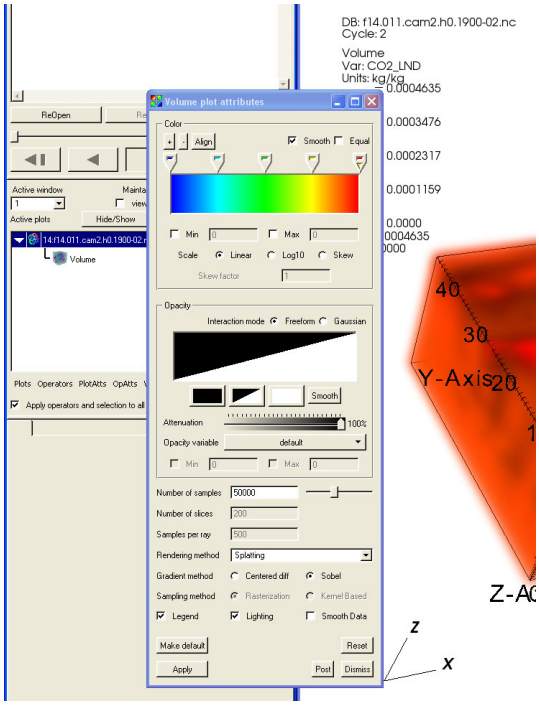

2. Click on Plots->Volume->CLDHGH->CO2_LND. A volume entry is now listed in the *Active plots* window.



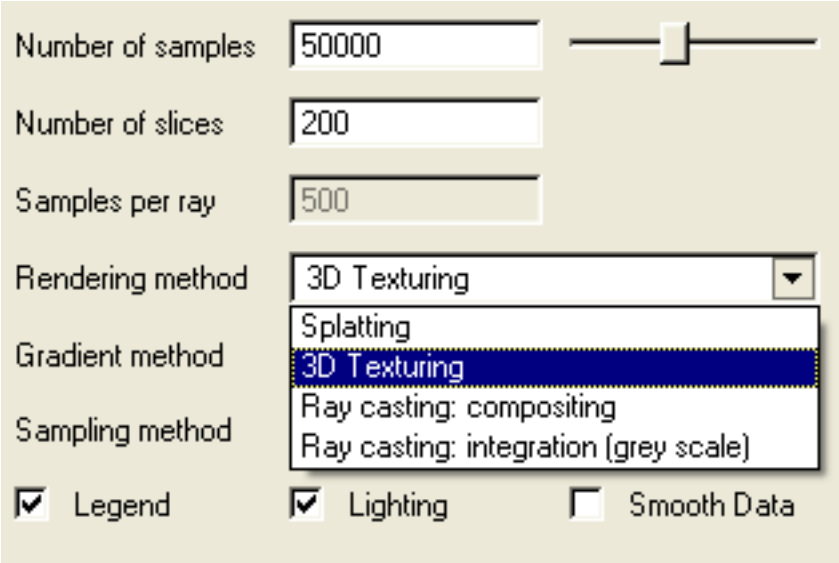
1. The volume will now appear in the rendering window. Observe the default transfer function in the rendering window (the color ramp and associated function to the immediate left of the color ramp).




2. Double-left-click on the new volume entry in the *Active Plots* window to reveal the *Volume plot attributes* pop-up window. This window allows the user to define the how the volume is rendered.



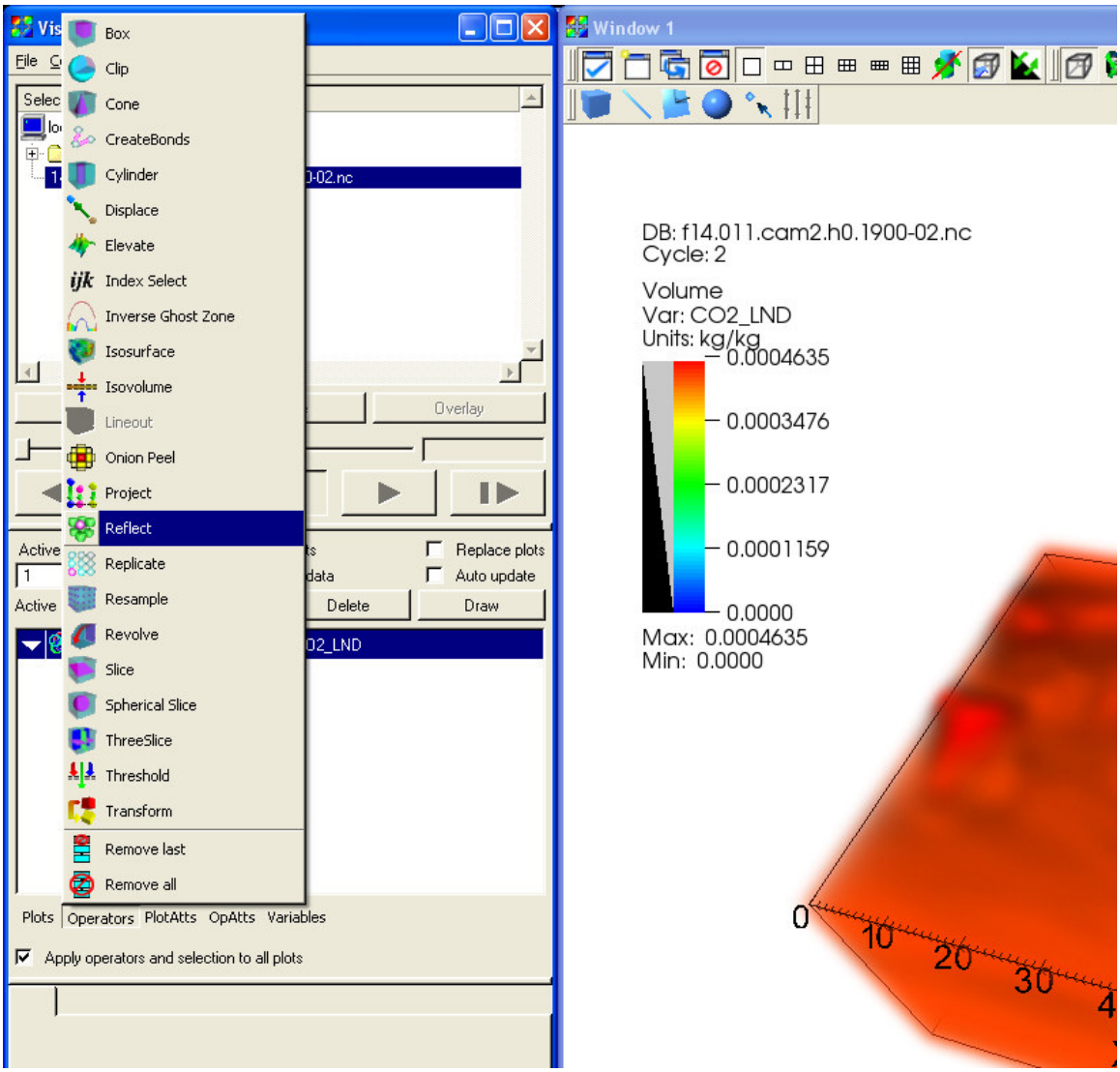
3. Observe the rendering options in the *Volume plot attribute* window. Generally, it is better to keep lower settings while building the visualization and then increase the settings to render presentation quality images. Leave the default settings for now.




We discovered earlier that as y-axis (lev) values increased altitude decreased. We need to reverse the y-axis again to make our visualization more intuitive by adding a reflection operator to the volume plot.

1. Select and highlight the volume plot in the active window by left clicking the text in Active plots window. Now left-click on the "Operators" item in the Active plots menu bar. Choose Reflect by left-clicking it.

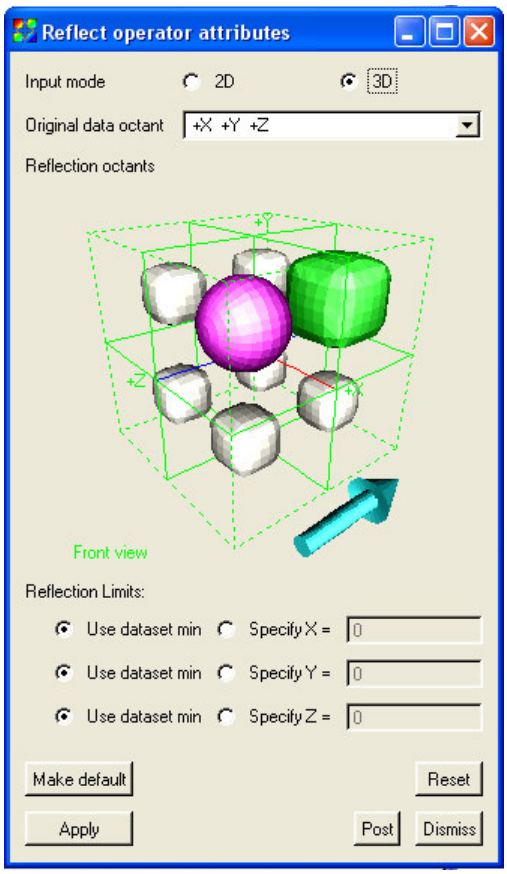
2. Observe the "twirly" to the left of the volume plot listing in the Active plots window. Left-clicking this icon will expand and collapse the plot tree. Left-click this twirly a couple of times to see the effect of expanding and collapsing the tree.

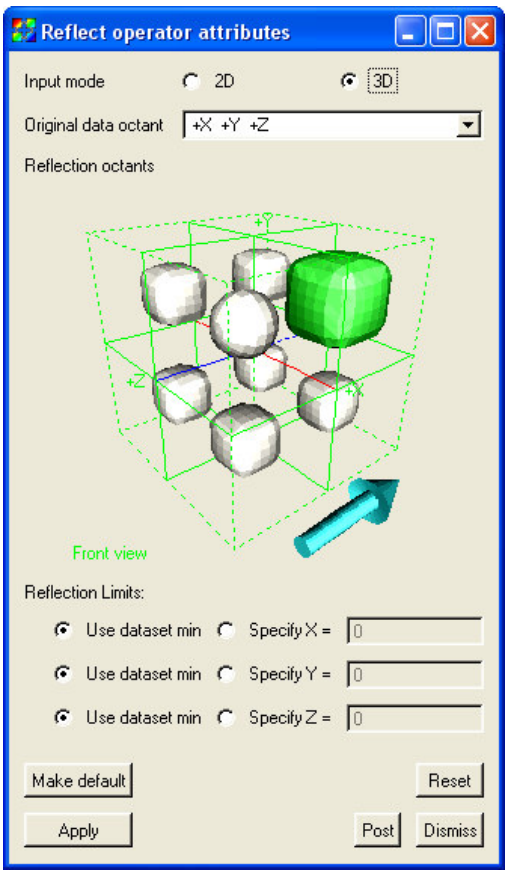



1. With the plot tree expanded, double-left-click the Reflect operator branch in the Active Plots window. The *Reflect operator attributes* window will appear.

2. Left-click the Input Mode radio 3D option in the Reflect operator attribute window.

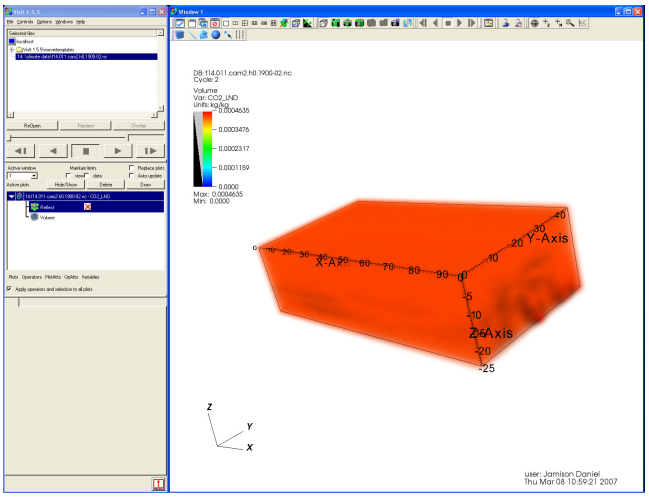
3. The pink sphere in the first quadrant represents the original data. Green boxes inside the other quadrants represent reflections. White boxes represent no reflection. A green box can be toggled on or off by clicking the box inside the quadrant. To reverse the y-axis, add a green reflection box to the left of the original quadrant as shown in the figure.




4. We only want to see the reflection, however and not the original data, so left-click on the pink sphere. Notice that the pink sphere representing our data disappeared.

5. Click on the Apply button to update the reflection operator. Click on the Dismiss button to close the *Reflect operator attribute* window.



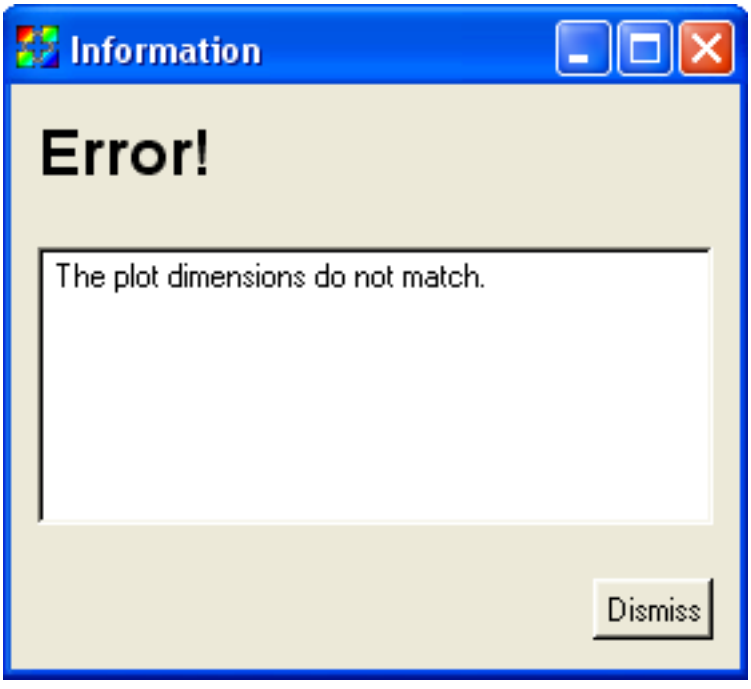
To visualize how the continents of Earth relate to our volume render we will need to import another data file. We will use a texture map, blue_marble.png, that has been aligned with the grid used in the f14.001.cam2 netcdf file.

1. Click File->Open File from the top level menu bar (or the ctrl-O hotkey). Browse to the blue_marble.png data file. Now the blue_marble.png file should be the active selected file in the *Selected files* panel list.

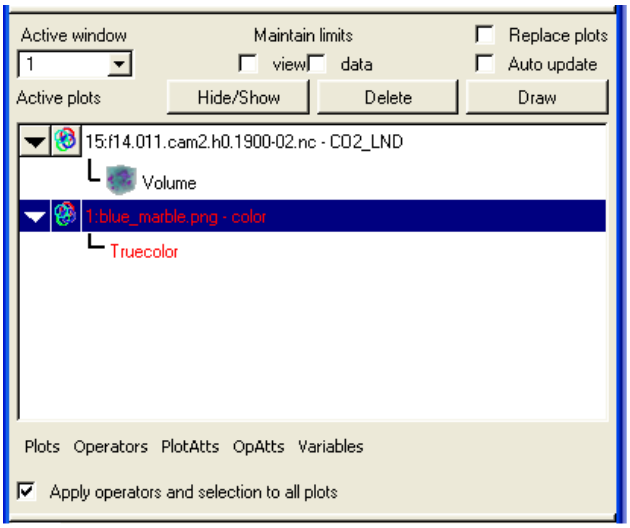
2. Notice the first button below the *Selected files* list. This button is context sensitive. It will either read *Open*, *Activate*, or *ReOpen*. In this case, it should read *ReOpen*. If we select the f14.011.cam2.h0.1900-02.nc file once again by left clicking on the filename in the *Selected files* list, the button will change to *Activate*. Activate indicates that Visit has already opened the file but the file is not currently the activated file. When creating plots, the plot is created using the active data file. Select the blue_marble.png file once again and insure that it is activated.

3. In the *Active plots* window click Plots->Truecolor->color. This will add a new top level pseudocolor plot into your *Active plots* window.

4. Select the blue_marble.png file from the *Active plots* list and left-click on Draw. A warning message will pop-up declaring that "The plot dimensions do not match".

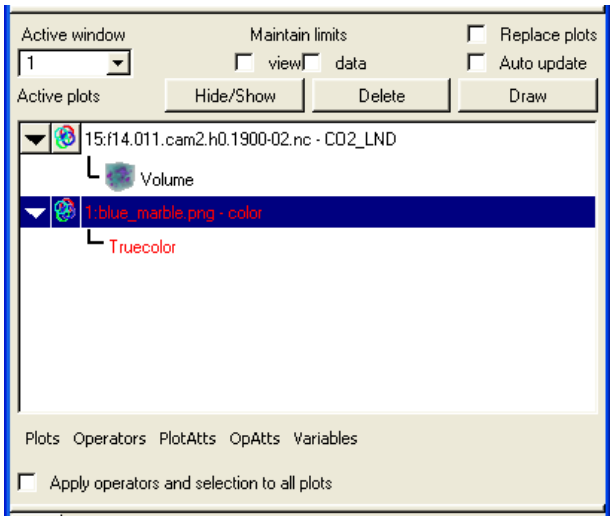


5. Observe that the blue_marble.png text in the *Active plots* window turned red to indicate an error.

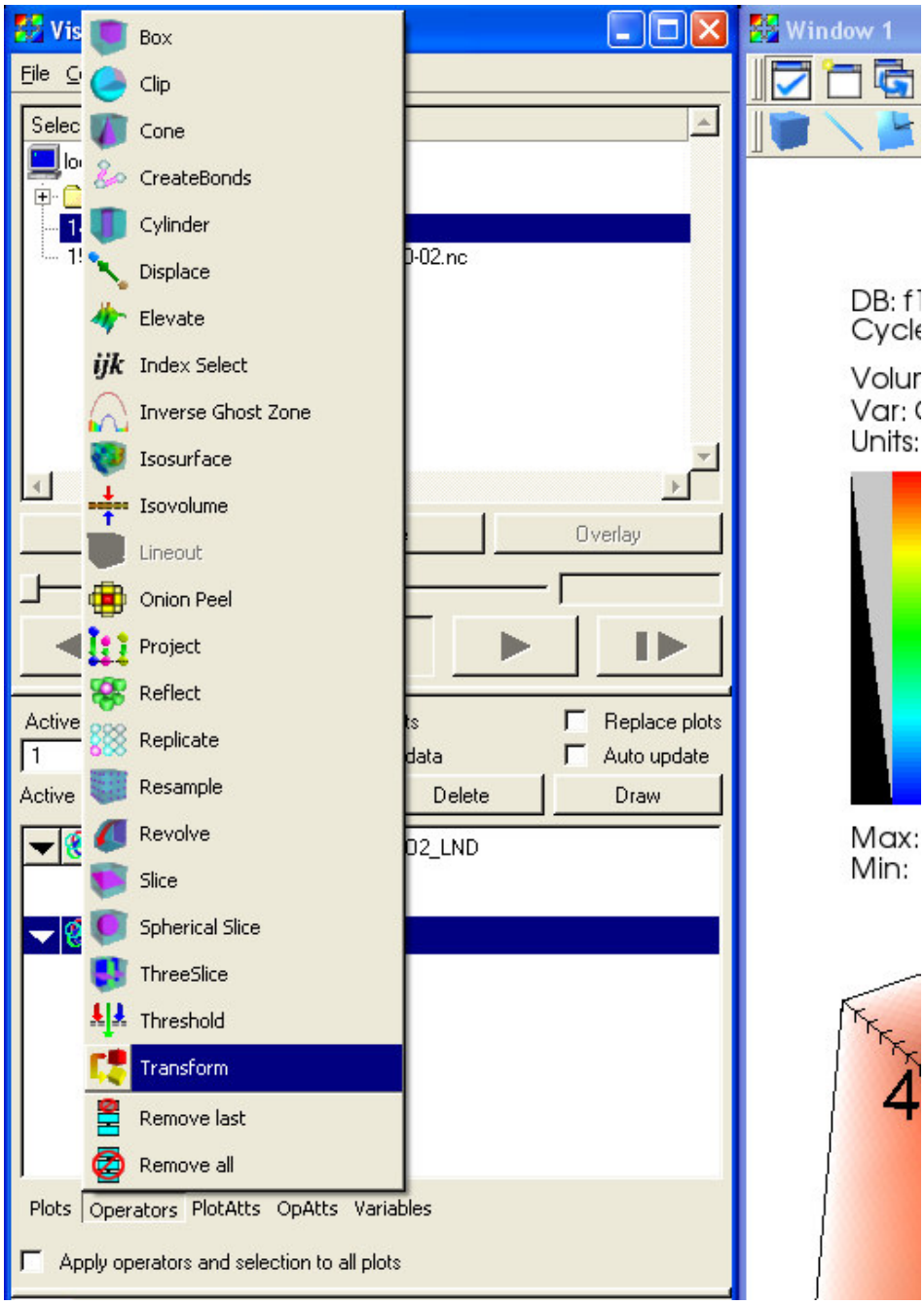



We need to convert this image from 2D space to 3D space. This can be accomplished by adding a transform plot operator. We only want to add this operator to the blue_marble.png plot and not our f14.011.cam2.h0.1900-02.nc plot. By default, VisIt will apply a new plot operator to all Active plots.

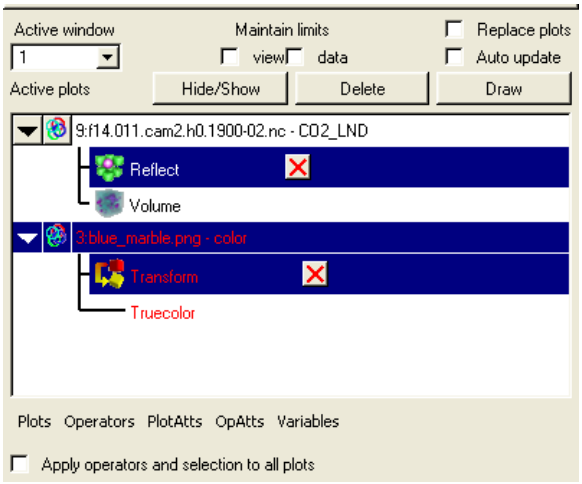
1. Uncheck the "Apply operators and selection to all plots" radio box at the bottom of the *Active plots* window. This informs VisIt that new operators should only apply to the selected plot in the *Active plots* window.



2. Ensure that the blue_marble.png plot is selected in the *Active plots* window and then click on Operators->Transform in the menu bar. The translate operator will only be added to our blue_marble.png plot.

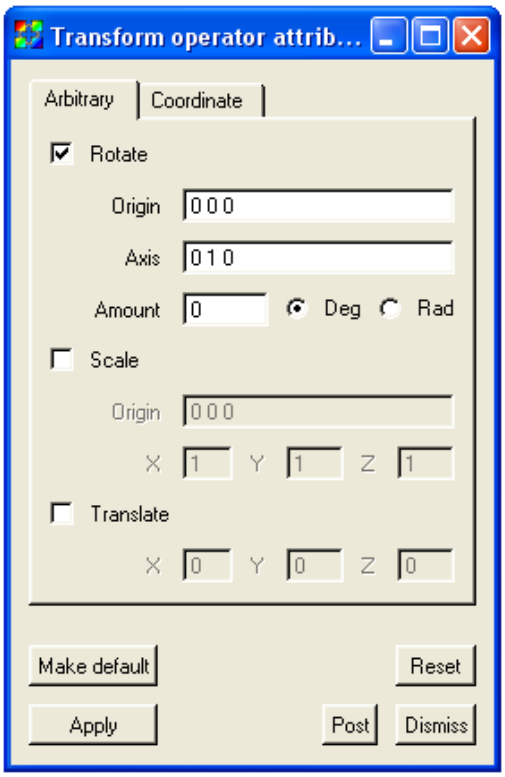


3. Double-left-click the “Transform” text branch from the blue_marble.png plot in the *Active plots* window. Observe that the *Transfer operator attribute* window has appeared.

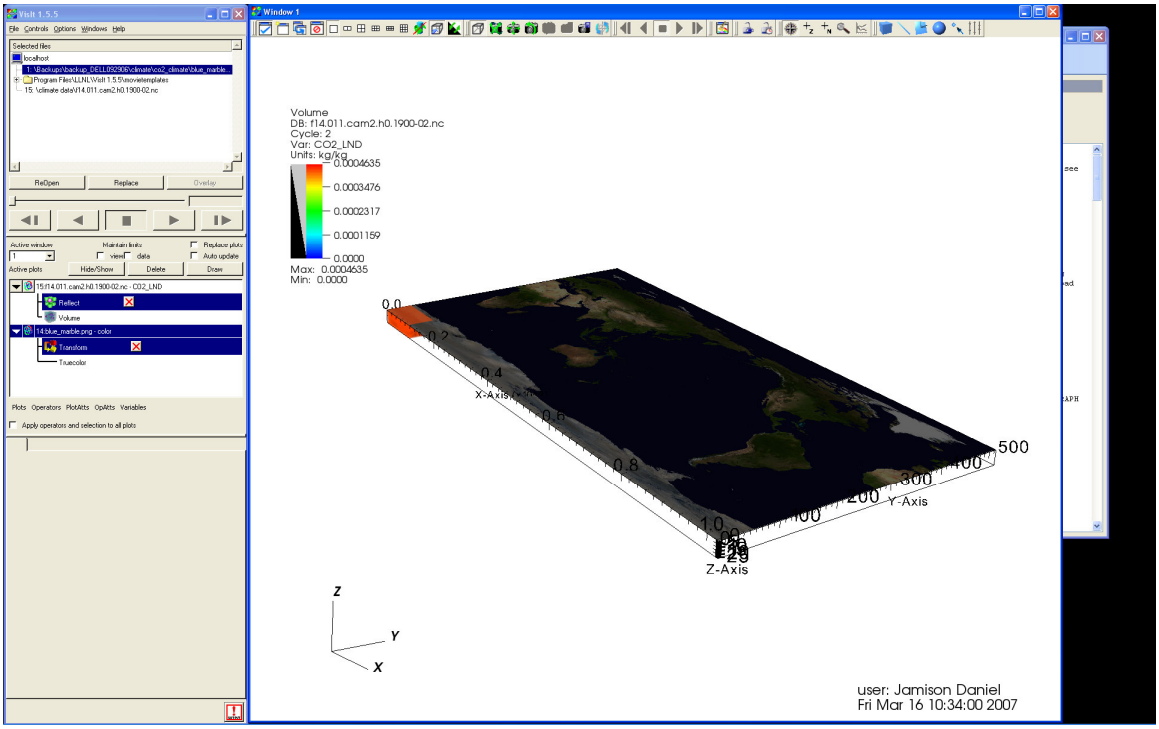



4. Left-click the Rotate radio box to add a checkmark. Now change the rotation axis to 0 1 0 using the keyboard. Leave the degrees of rotation to 0. This informs VisIt that we wish to use 3D space for this truecolor plot.

5. Click Apply button in the *Transfer operator attribute* window. Click the Dismiss button in the *Transfer operator attribute* window.



6. Observe that the blue_marble texture is visible in the rendering window. It may appear too dark however. It may appear this way because the lighting model is being calculated. There is a light source at the camera so if the texture plane is normal with the eye position, we see the texture fully lit. As we tilt the plane away from the camera position, it appears darker. We need to correct the dark texture by turning off the lighting calculations.

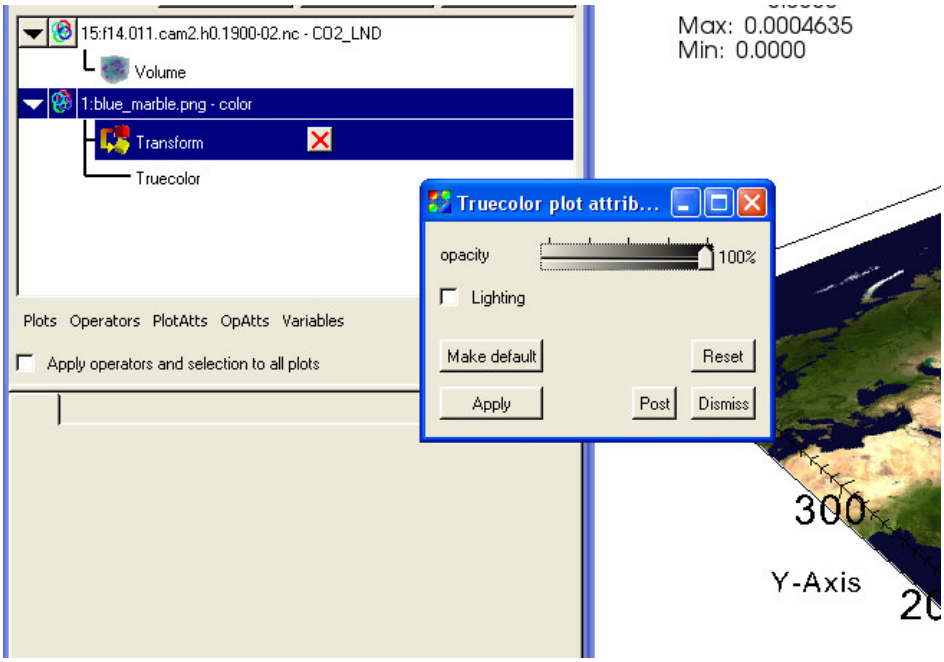



7. Double-left-click on the blue_marble text in the *Active plots* window to open the *Truecolor plot attributes* window.

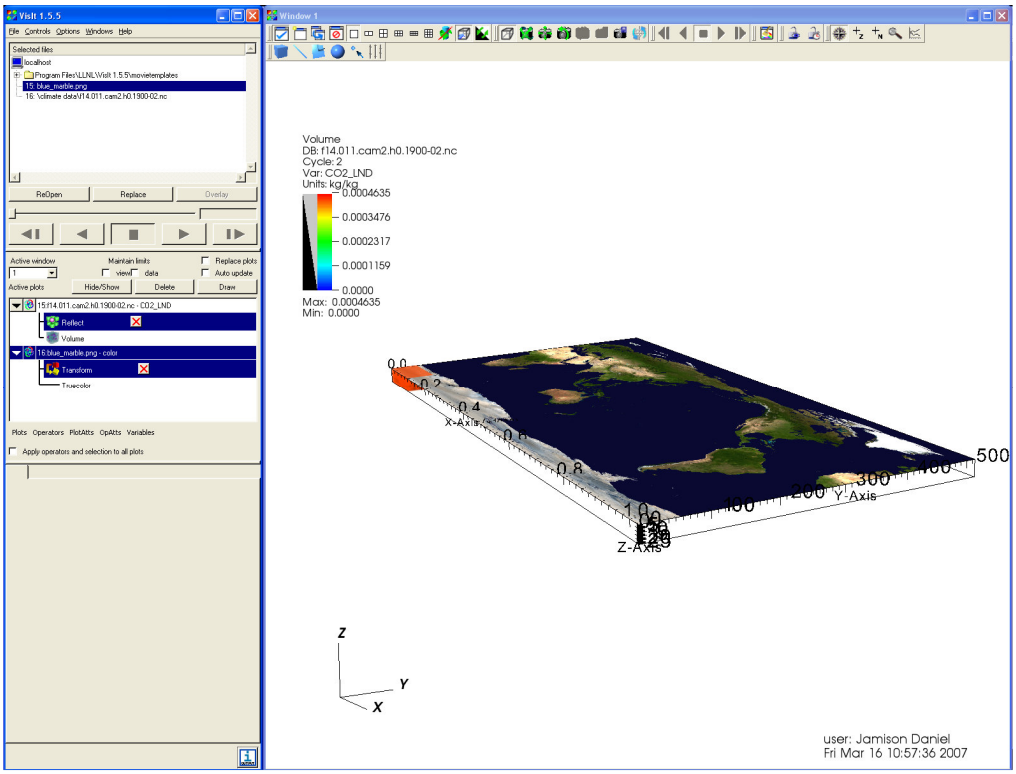
8. Uncheck the Lighting radio box in the *Truecolor plot attributes* window.

9. Click the Apply button in the *Truecolor plot attributes* window.

10. Click the Dismiss button in the *Truecolor plot attributes* window. .

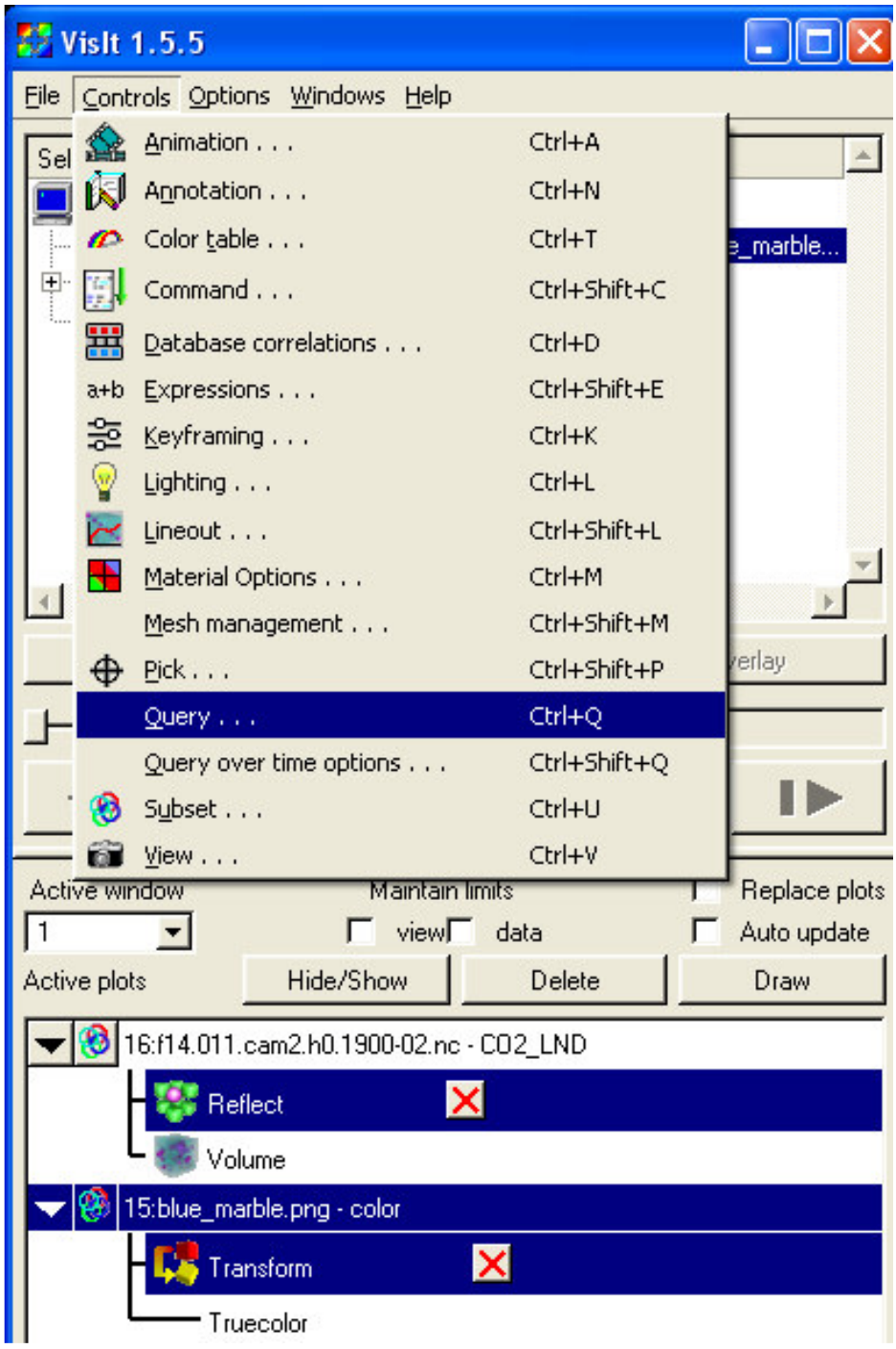



11. Observe that the blue_marble texture now appears to be fully lit regardless of position.

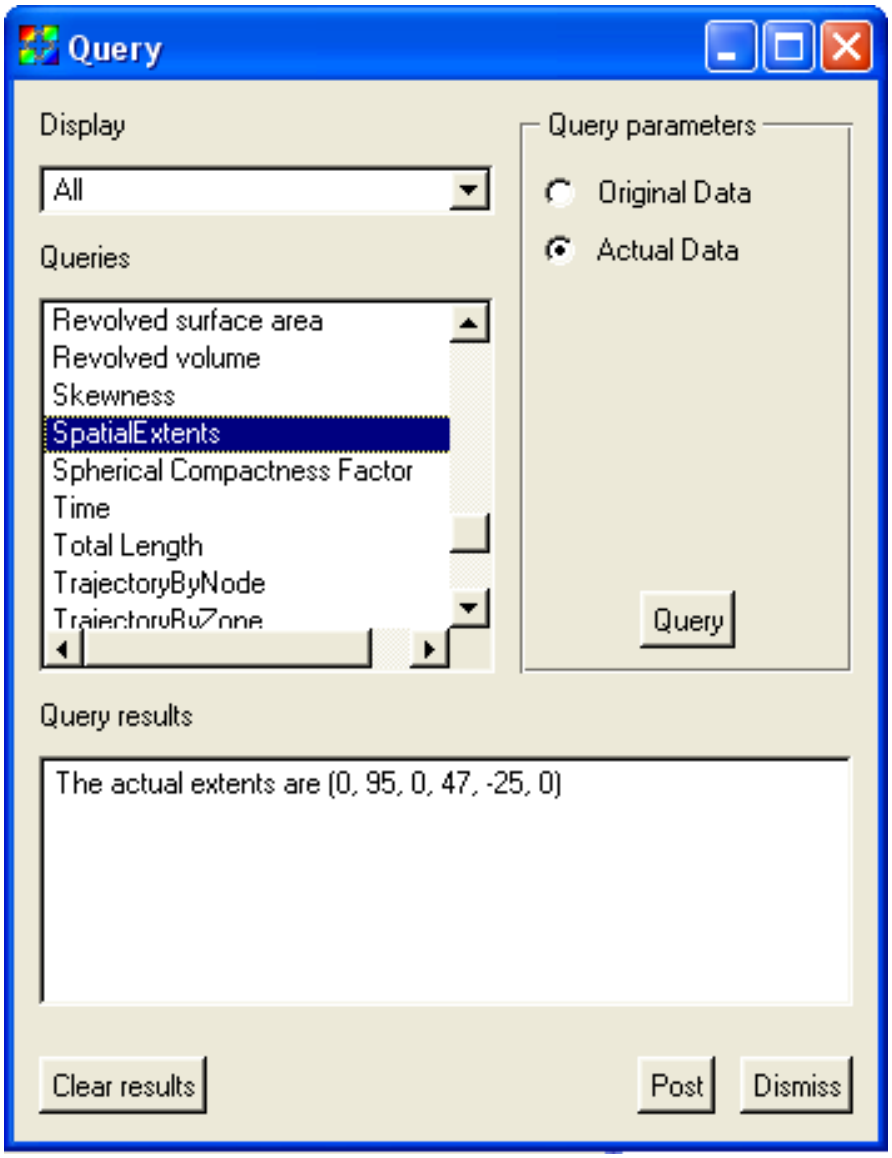


The texture size in the rendering window is very large compared to the volume plot. It is also on the top of the volume instead of the bottom of the volume where we would normally expect it.

1. Highlight the f14.011.cam plot by clicking on the top level text in the *Active plots* window. Click on Controls->Query from the top panel (or press ctrl-Q to hotkey). The query window will appear.

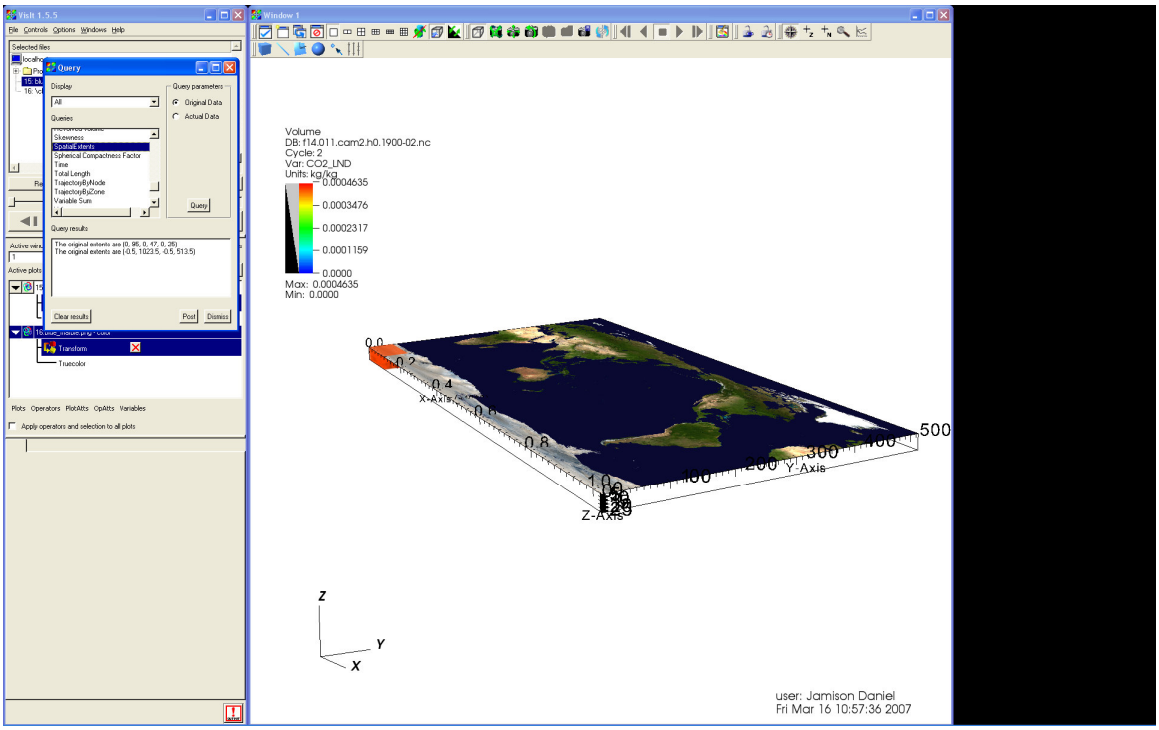


2. Observe the queries options listed in alphabetical order in the Queries window. Scroll down and highlight “Spatial Extents” by left clicking the text. Now click the Query button.




3. Observe the results of the f14.011.cam2 Spatial Extents query in the *Query results* window, “The original extents are (0. 95, 0, 47, 25)”.

4. Highlight the blue_marble.png plot by left clicking the top level text in the *Active plots* window. Now click on Query button once again. Observe the spatial extents of the blue_marble texture, “The original extents are (-0.5, 1023, -0.5, 513.5)”.



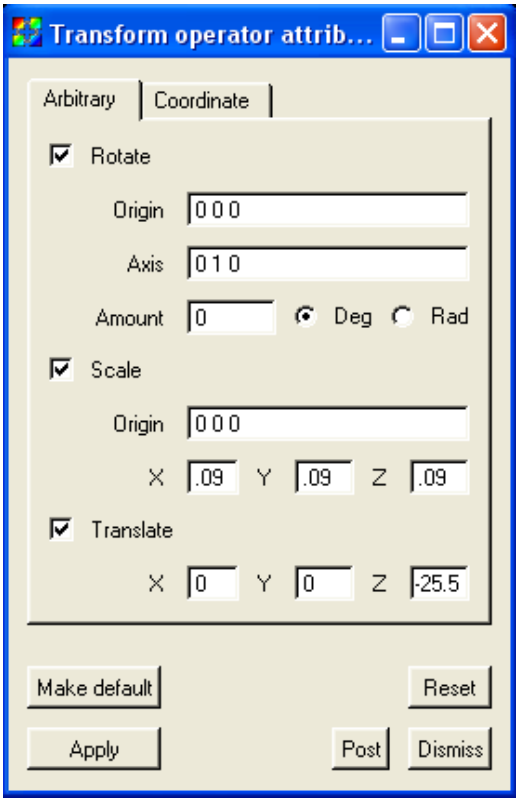

5. Dismiss the *Query* window by clicking the Dismiss button in the *Query* window.

6. Open up the *Transform operator attribute* window by double left-clicking on the Transform operator text under the blue_marble active plot listing in the *Active plots* window.

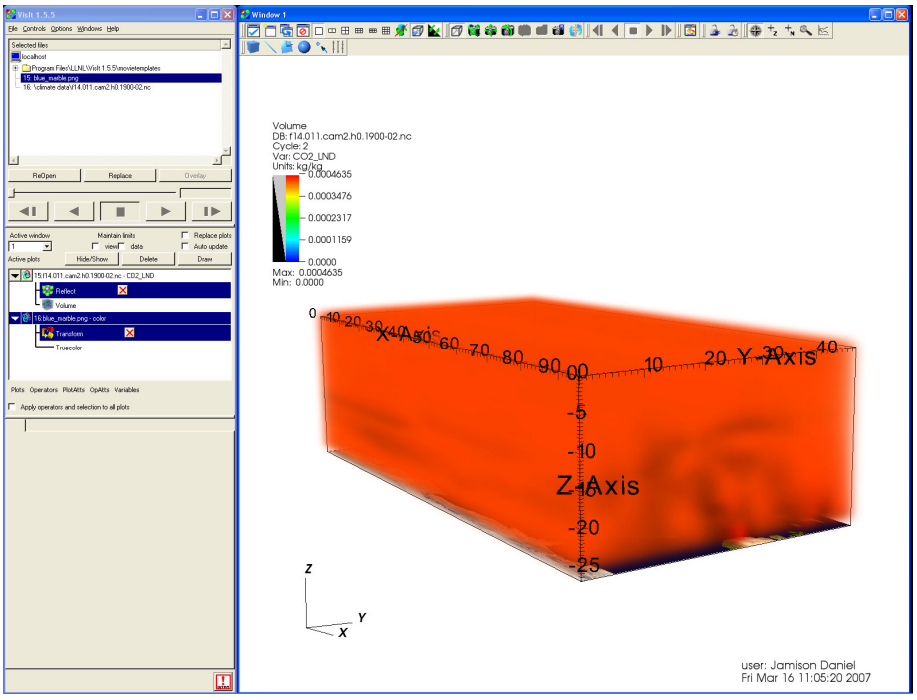
7. Observe that the horizontal extent of the volume is 95 and the horizontal extent of the texture is 1024. The result of dividing 95 by 1024 is 0.0927734375. This result is the scaling factor. The depth of the volume along the z axis is 25 and the texture plane is on -0.5.

8. Click on the Scale and Translate radio boxes in the Transform Operator Attribute window to add a checkmark. Enter the scaling value 0.0927734375 into the X, Y, and Z boxes under Scale. Enter the z-axis translate value -25.5 into the Z box under Translate, leaving X and Y at 0.

9. Click the Apply button and Dismiss the *Transform Operator Attribute* window.

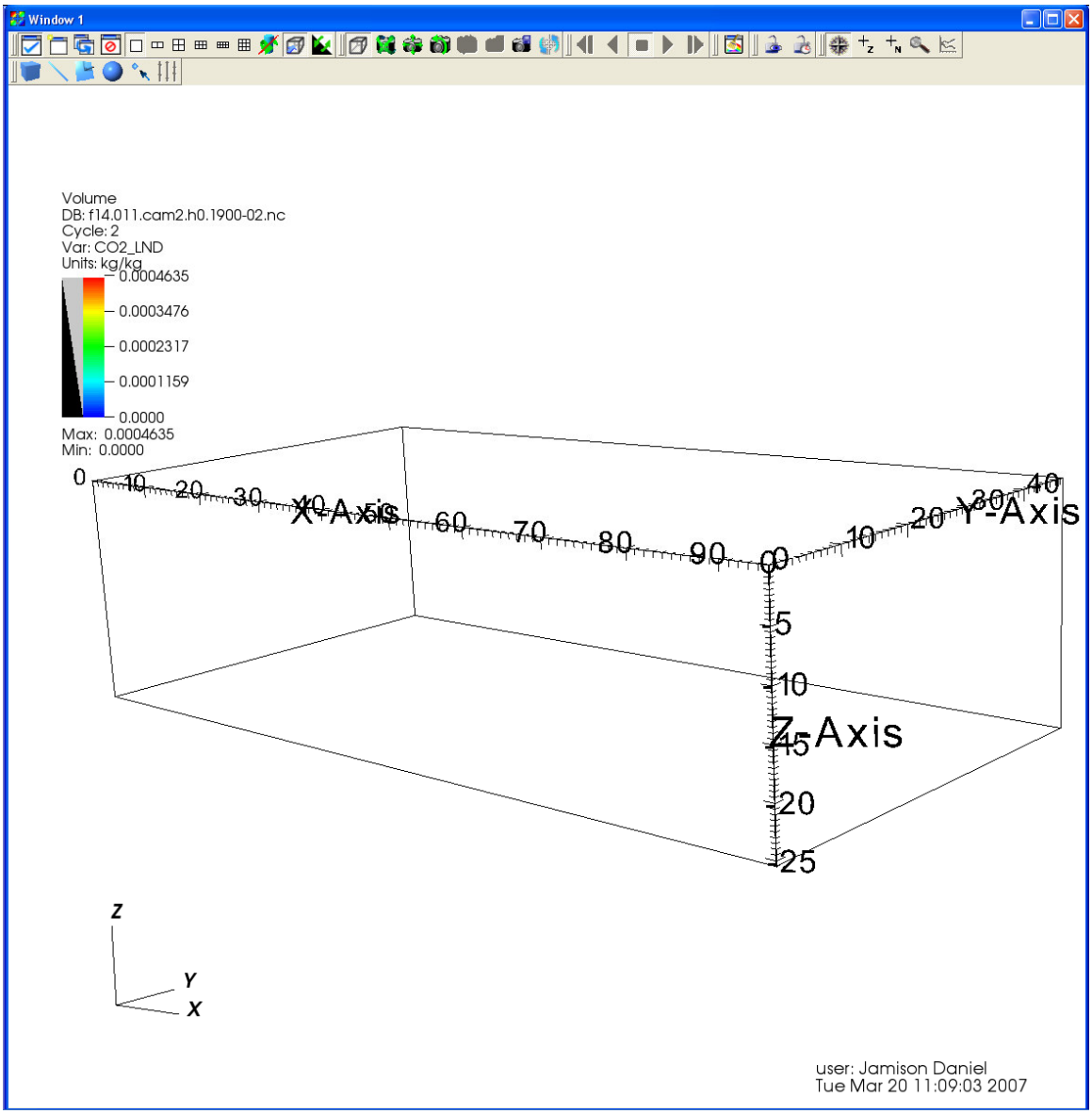



10. Observe that the continent texture is now correctly aligned with the volume.



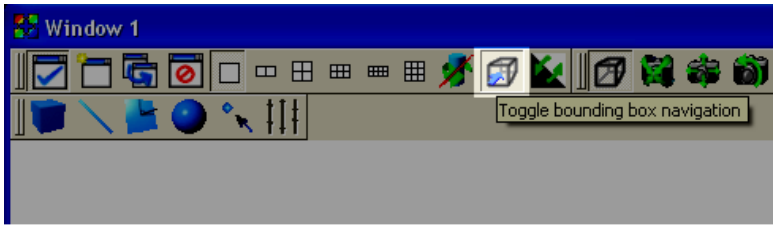
Performance Considerations

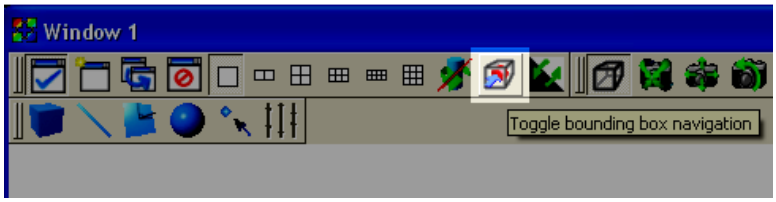
1. Left-click on hold anywhere in the rendering window. Without releasing the mouse button, move the position of the mouse. This will change the camera position of the visualization. Notice that while the mouse is moving a bounding box appears around the plots.



There are several performance and configuration options that the user can manipulate. Depending on your hardware resources available, you may want to turn off bounding box navigation.

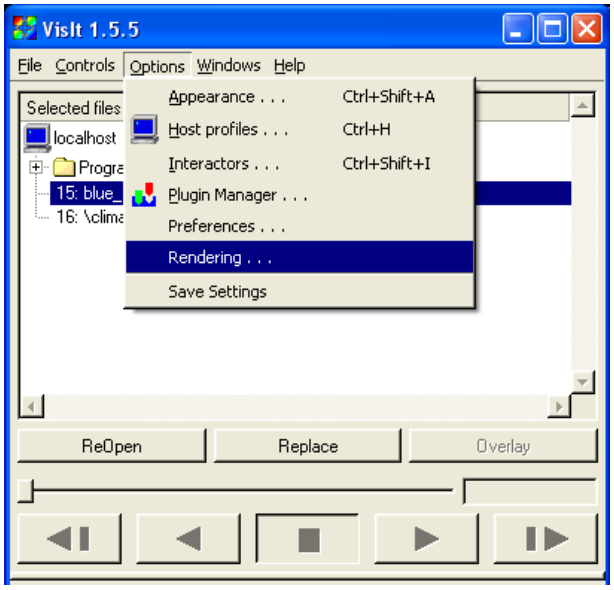
2. Toggle the bounding box navigation button at the top of the rendering Window to off.



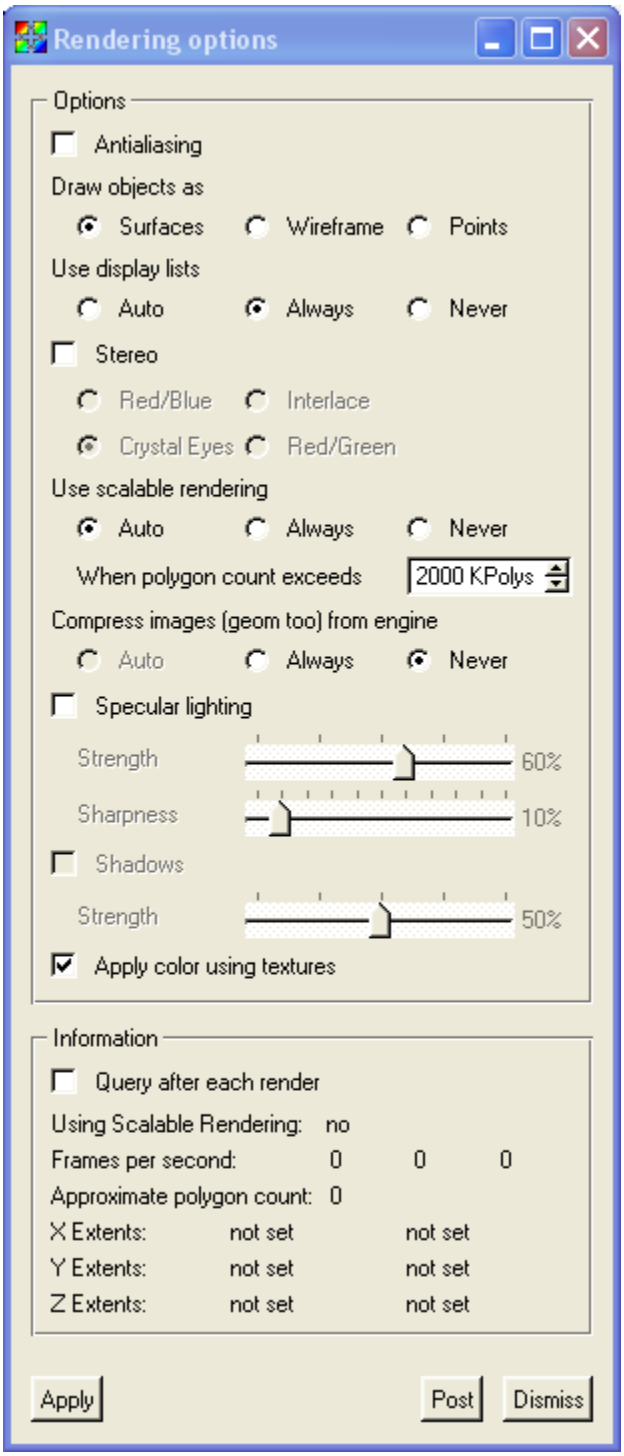




3. Left-click and hold in the rendering window and move the mouse to manipulate the view position. Observe that the bounding box does not appear and the volume can be seen constantly while manipulated the camera at the expense of greater computational costs.

4. Click on the Options->Rendering… menu on the top level menu bar



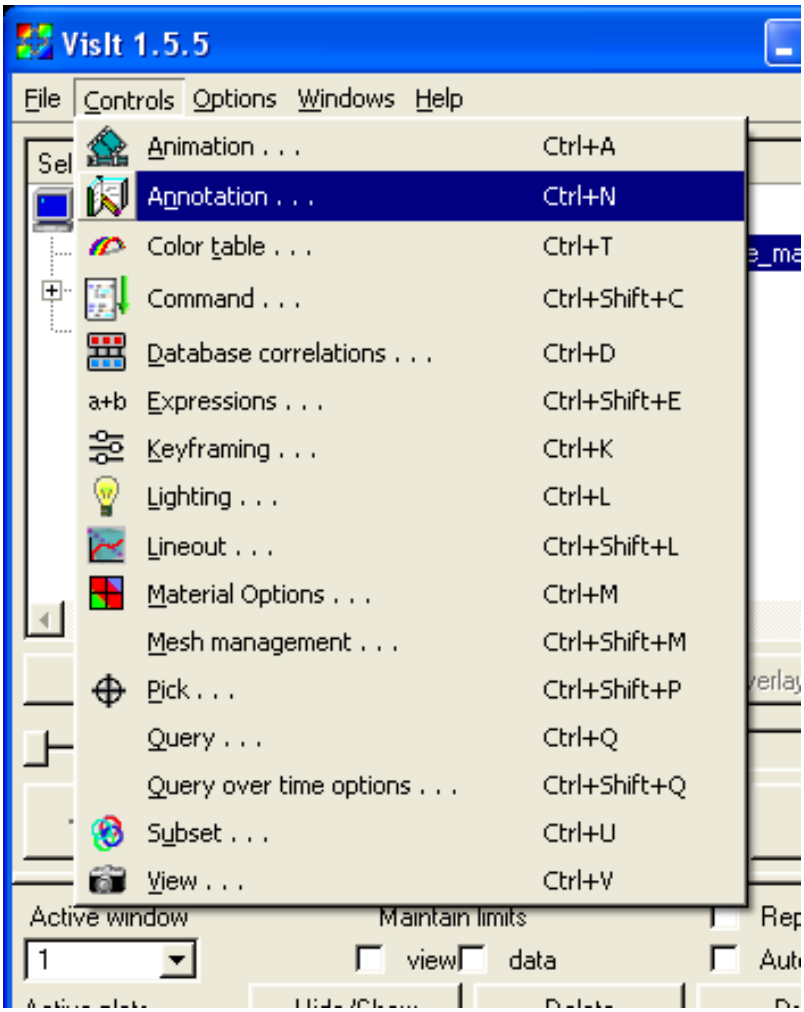
5. Change “Use display lists” from “Auto” to “Always” by left-clicking the appropriate radio box. This allows OpenGL to save certain rendering states possibly reducing future rendering expenses.



Annotation

6. Activate the f14.011.cam2 volume in the *Active plots* window by left-clicking it.

7. To open the *Annotation* window click on Controls->Annotation from the top level menu bar (or hotkey ctrl-N).

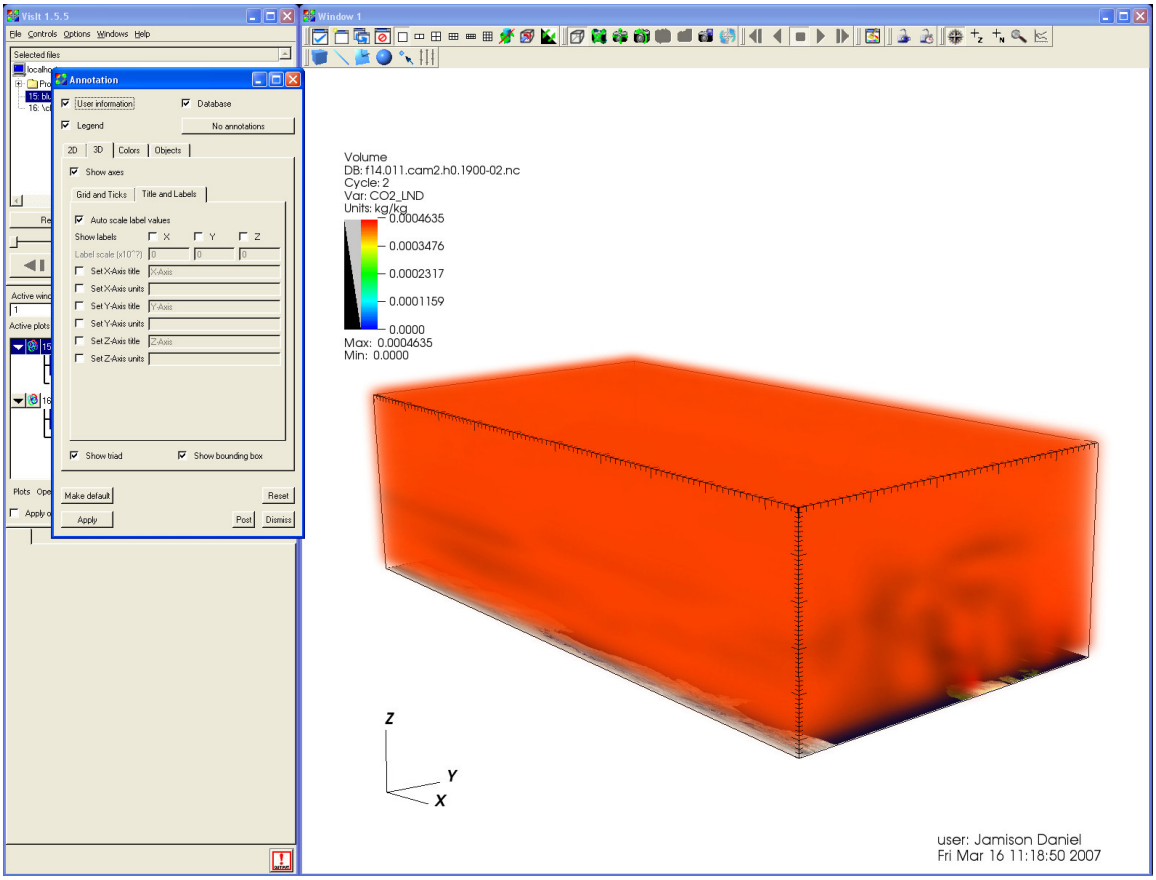



8. Left-click on the 3D tab in the *Annotation* window.

9. In the 3D tab, left-click on the Title and Labels tab.

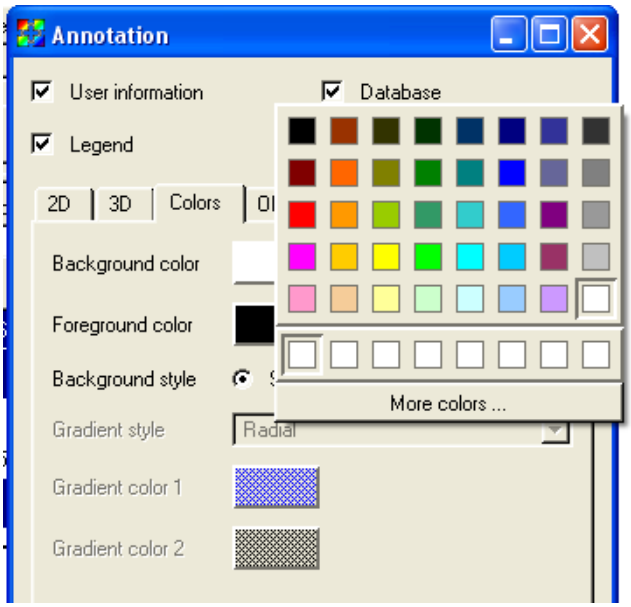
10. Uncheck the X, Y, and Z radio boxes under Show labels.

11. Left-click the Apply button. Observe that the rendering window is now not as cluttered.



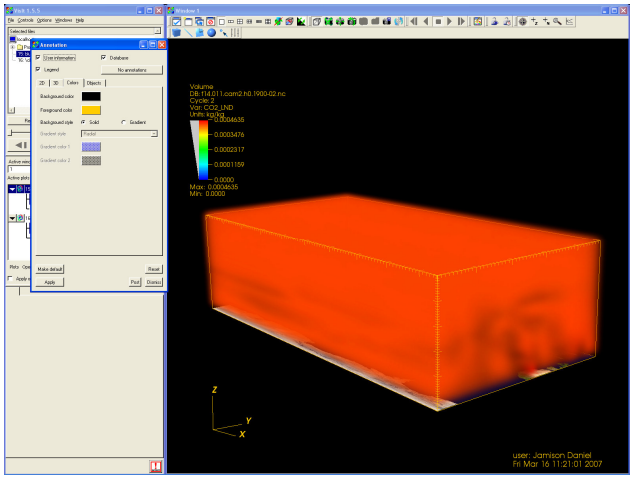

12. Left-click on the Colors tab.

13. Left-click on the white box directly to the right of “Background Color”. This reveals the color selector. Choose the black color by clicking on the top left black square in the color selector window.



14. Click the Apply button in the *Annotation* window to update the rendering window. Observe that the background is now black.

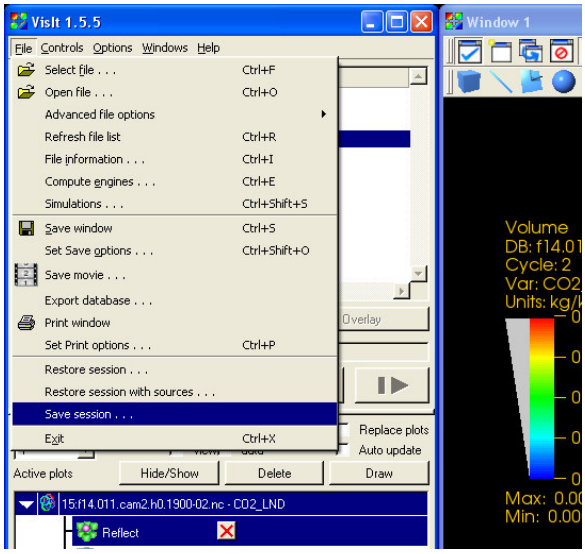
15. Using the color selector, change the foreground color by clicking on the foreground color box and selecting a yellow/orange. Observe that the colors of the text and axis information are now better contrasted against the black background.



## Saving the Session

1. Click on the File menu from the top level menu bar and click "Save session…".

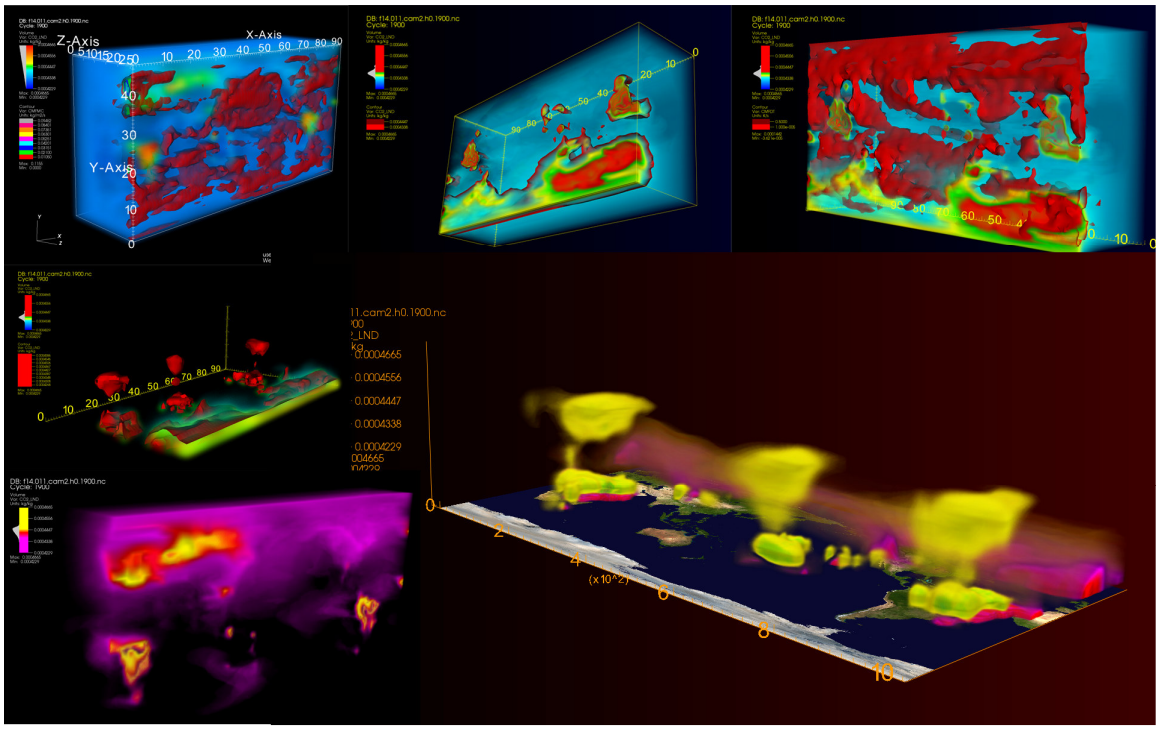
2. Enter the preferred name and location of the .vses session file. This session file can later be restored by choosing File->Restore session… from the top-level menu bar.



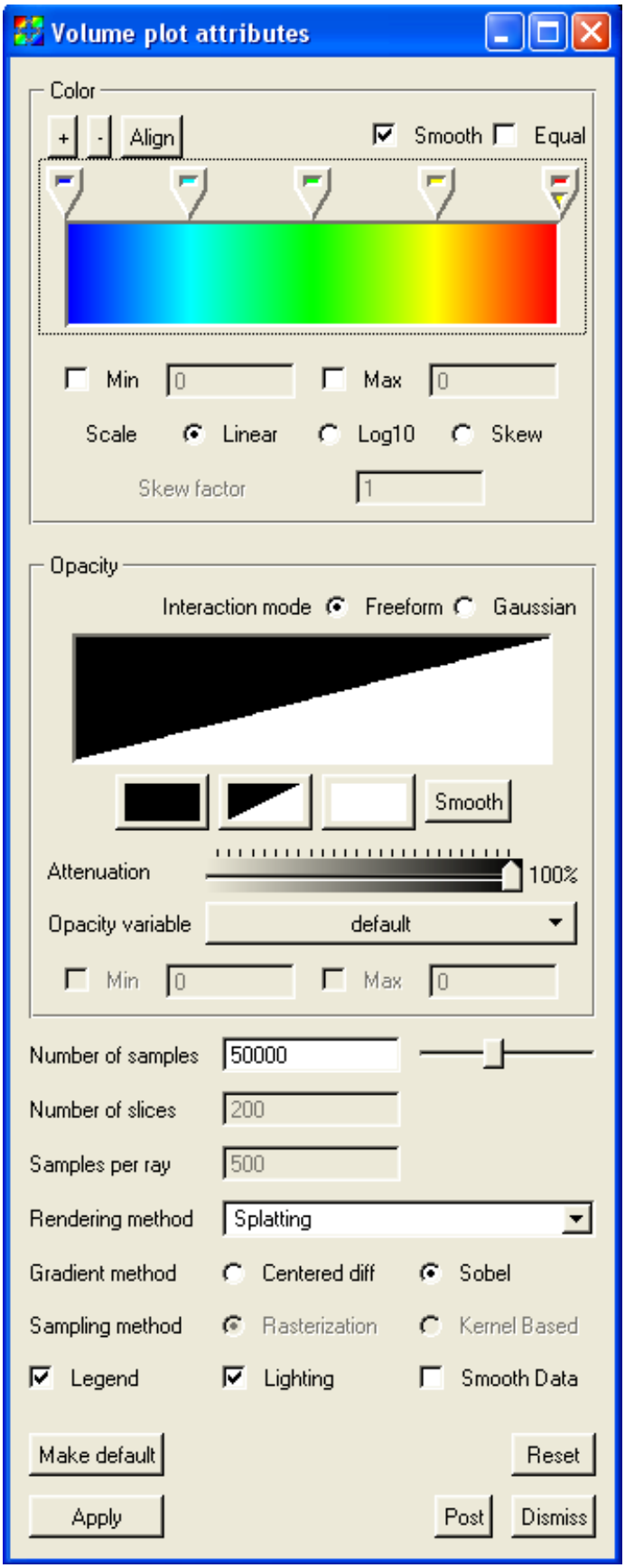
Building the Transfer Function

As stated before, we are looking for $CO_2$ plumes that are forming as a result of the green $CO_2$ in the Amazon Basin, the Congo, and Eastern Europe. These plumes are not visible from our current rendering window. We need to build the transfer function appropriately.

Exploration and communication with the domain scientists are critical to finding an appropriate transfer function. The following graphic illustrates several renderings that were used as a communication tool with the climate scientists that allowed the appropriate transfer function to be discovered.



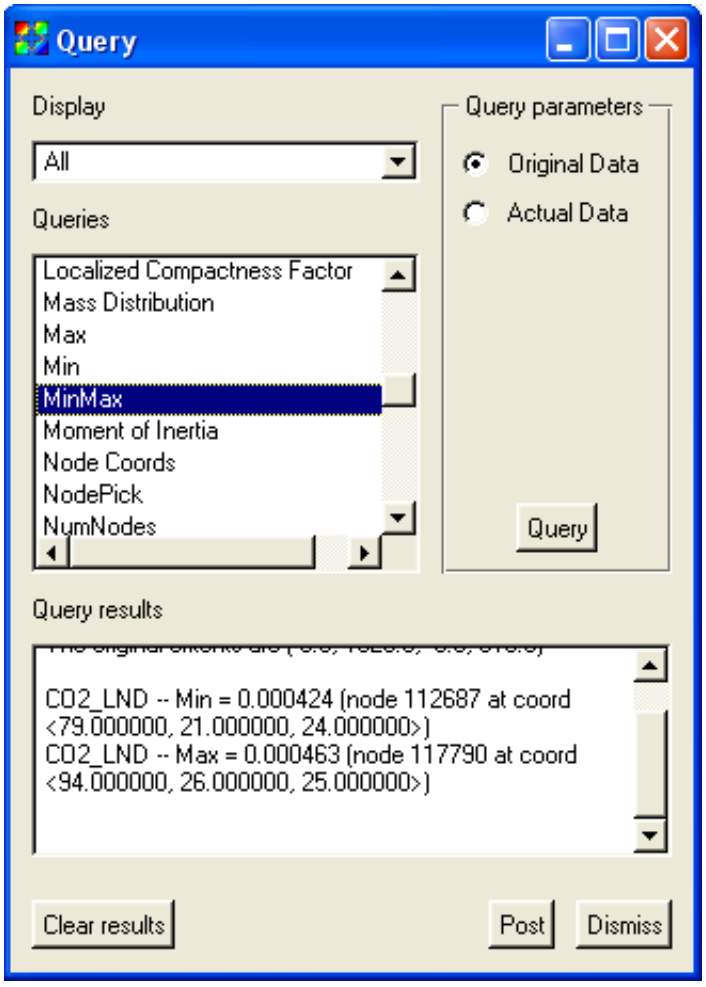

1. Double-left-click on the top level f14.001.cam2 text in the *Active plots* window to open the *Volume Plot Attribute* window. Our simple transfer function slopes linearly from right to left. The vertical position of the line represents opacity while the horizontal position represents data values.


Volume plot attributes
Color
+
-
Align
Smooth
Equal
Min
0
Max
0
Scale
Linear
Log10
Skew
Skew factor
1
Opacity
Interaction mode
Freeform
Gaussian
Smooth
Attenuation
100%
Opacity variable
default
Min
0
Max
0
Number of samples
50000
Number of slices
200
Samples per ray
500
Rendering method
Splatting
Gradient method
Centered diff
Sobel
Sampling method
Rasterization
Kernel Based
Legend
Lighting
Smooth Data
Make default
Reset
Apply
Post
Dismiss

2. Ensure that the f14.011.cam2 plot is active in the *Active Plots* window and navigate to the Query menu using the mouse (or hotkey ctrl-Q) to bring up the window.

3. Select the MinMax text in the Queries scroll window and then click the Query button.

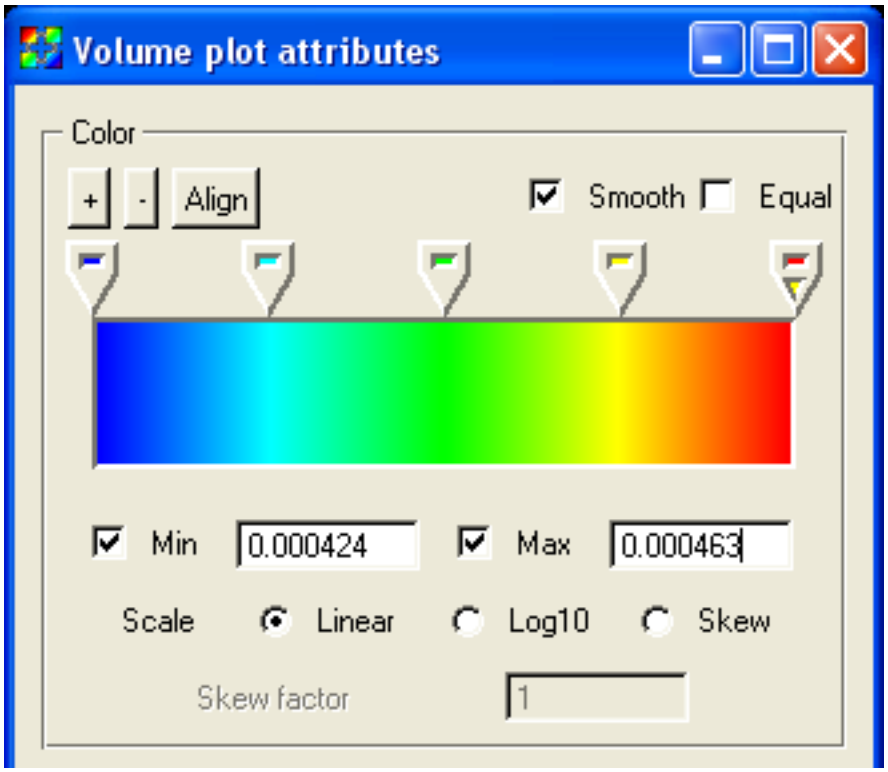
4. Observe in the Query results window that the maximum value is .000463 and our minimum value is .000424.




5. Return to the *Volume Plot attribute* window by double-left-clicking the f14.001.cam2 text in the Active plots window.

6. Click the radio box to the left of “Min” to add a checkmark. Do the same for “Max”.

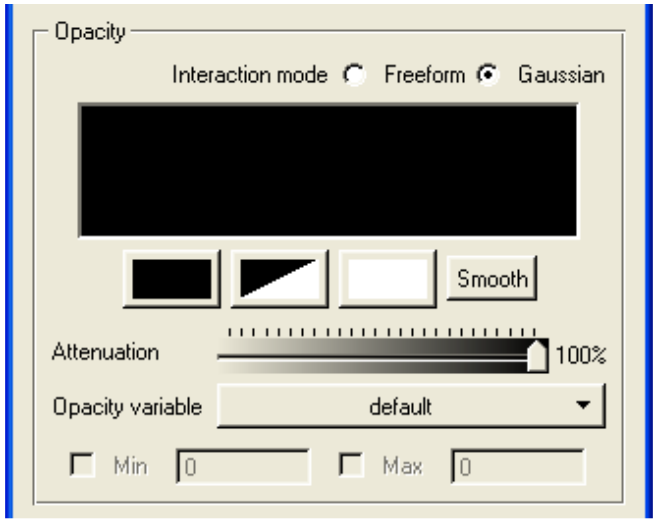
7. Enter the values that we observed from the MinMax query into the appropriate text box for Min and Max.



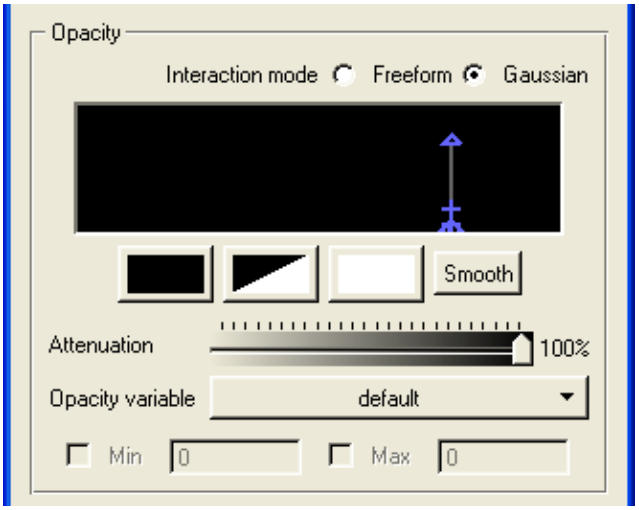

8. Click on the first small black rectangle button underneath the transfer function viewport. This will clear the transfer function canvas.

9. Observe the two Interaction mode options, Freeform and Gaussian. Freeform mode lets you click and draw on the transfer function viewport window directly. Using this method with the Smooth button can be an effective way to define a transfer function.

10. Click on the radio box for the Gaussian method.



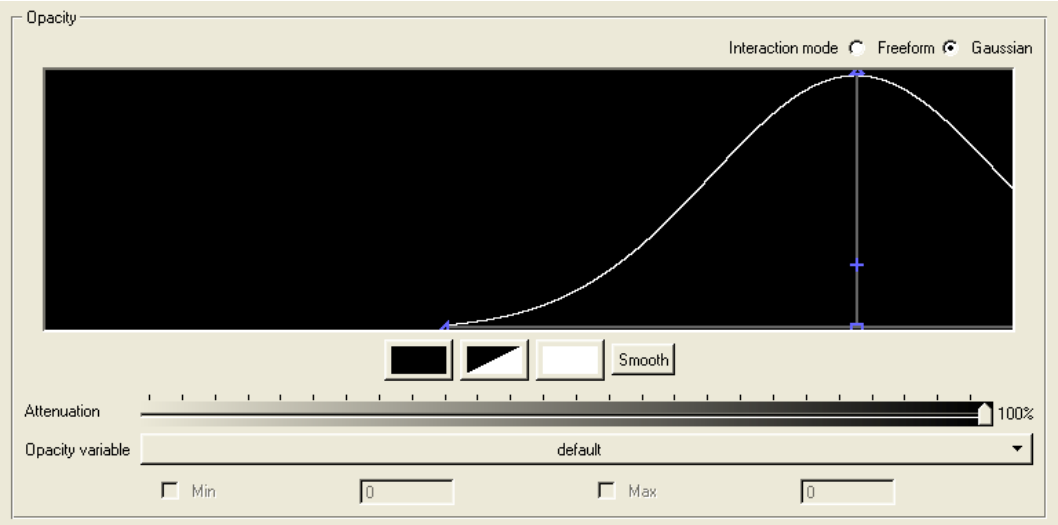
11. Click near the top left corner of the transfer function viewport window. This will place a Gaussian curve in the viewport window with several control handles.



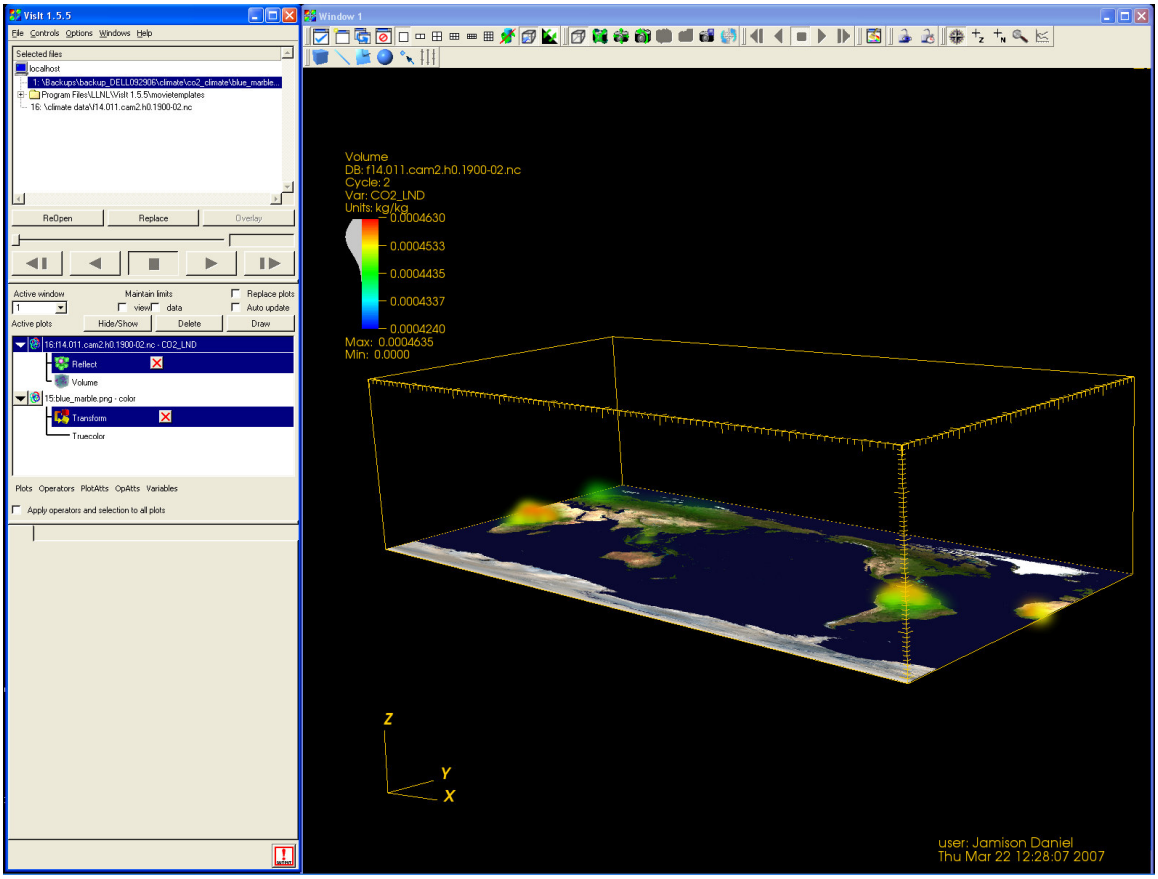

12. Hover your mouse cursor over a corner of the Volume Plot Attribute window. Your cursor should change to an icon that indicates a window resize.

13. Left-click-and-hold-and-drag to resize the window to enlarge the transfer function viewport.

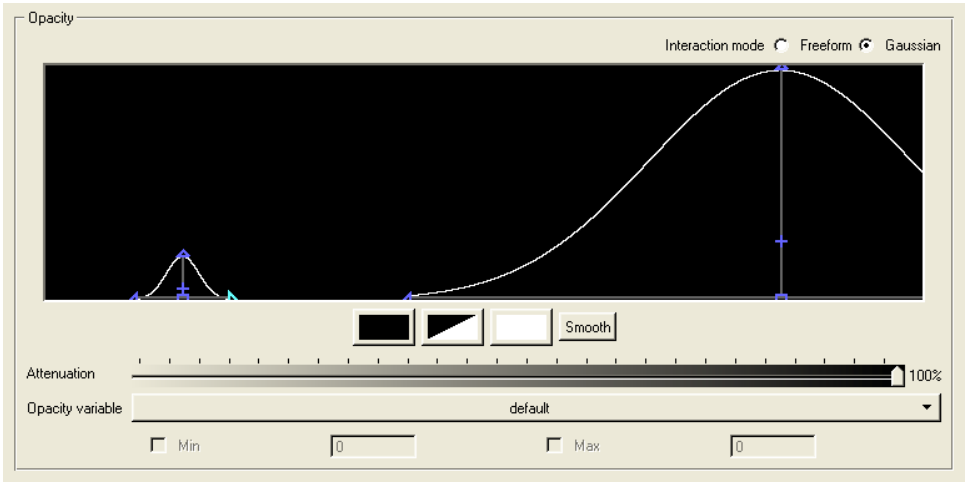
14. Left-click-and-hold one of the lower handles of the Gaussian curve. If you clicked the left handle, drag it to the left. If you clicked the right handle, drag it to the right. The curve will remain symmetric. If you wish to delete a Gaussian curve, simple right-click on any handle.



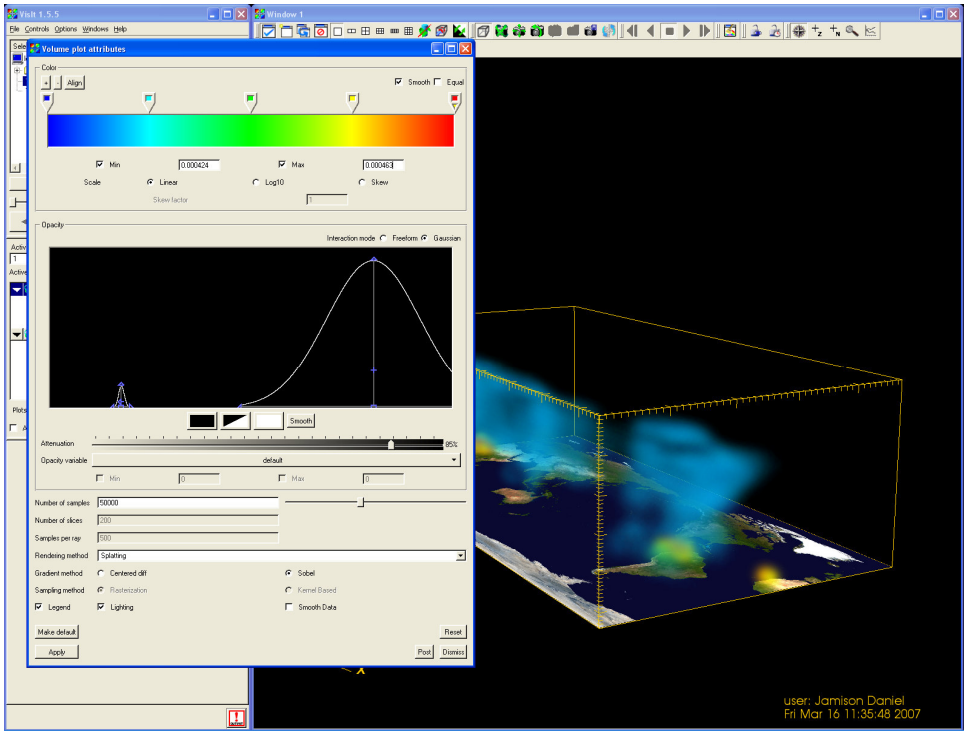
15. Click Apply. Our rendering window is now updated to show the green $CO_2$ near the Amazon Basin, the Congo, and Eastern Europe. However, we still do not see the $CO_2$ plumes themselves. For this we will need another Gaussian curve.




16. Add another Gaussian curve to the transfer function viewport and shape it as shown below. Notice that this curve is a much smaller height than our first curve, thus the opacity values will be much more transparent.



17. Click the Apply button.



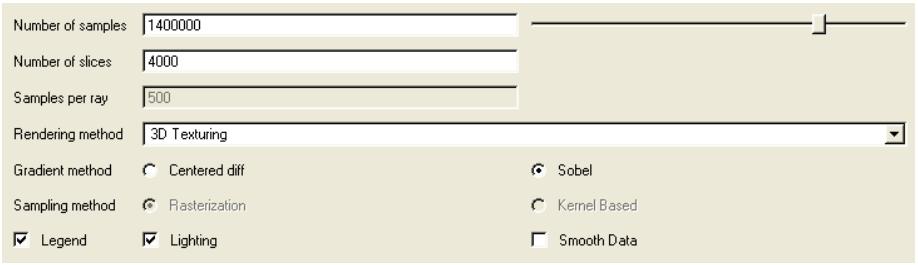

## Increasing Rendering Quality

Below the transfer function viewport window, there are several rendering options that can be changed to increase rendering quality or increase rendering speed.

1. Change the rendering technique to 3D Texturing by selecting 3D Texturing from the Rendering Method drop down menu.

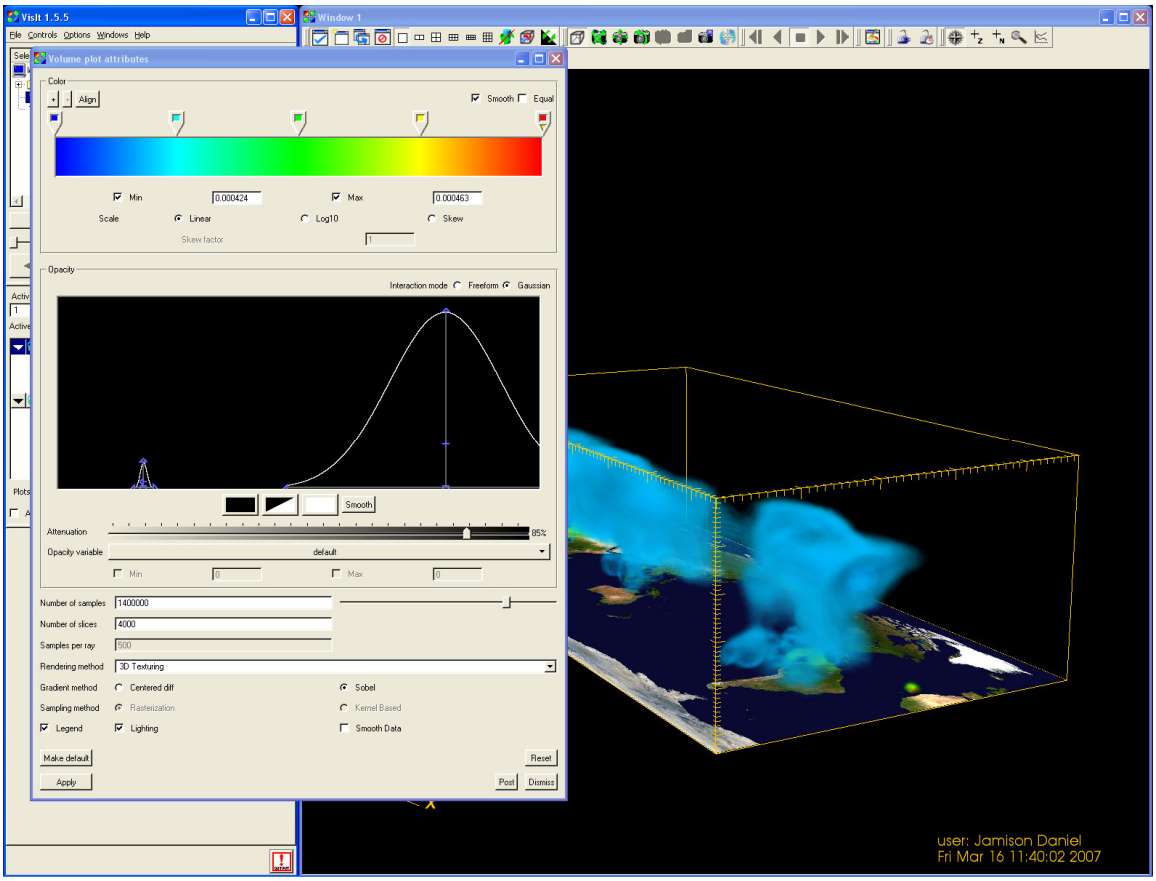
2. Increase the Number of samples to 14000000 by either typing it into the text box for “Number of Samples” or use the associated slider bar.

3. Increase the number of slices by typing in 4000 in the text box associated with “Number of Slices”.



4. Click the Apply button to view the results, observing that the rendering time may have increased and the rendering quality has also increased.

5. Click the Dismiss button to close the *Volume plot attribute* window.



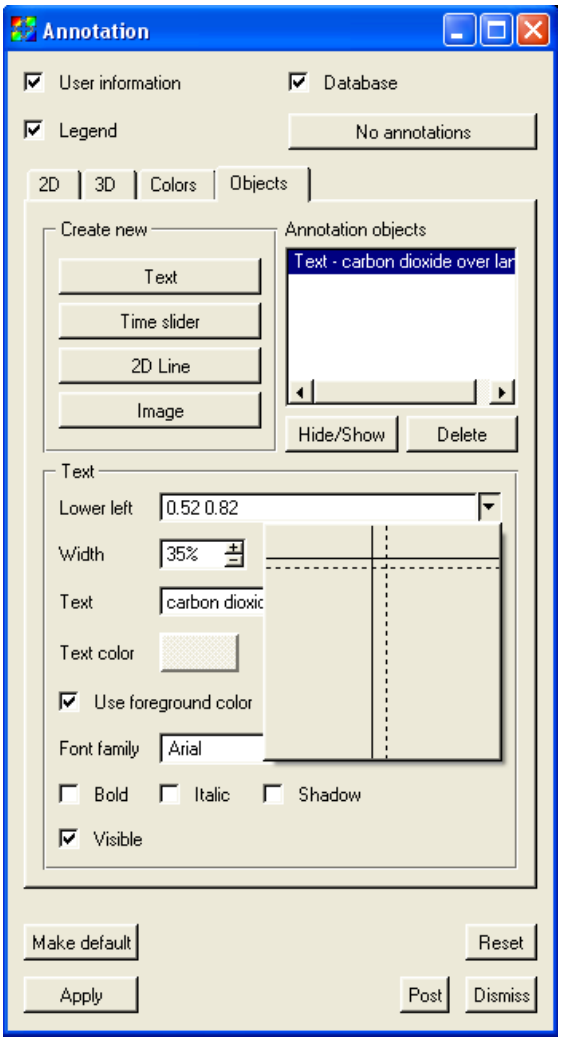

1. Return to the Annotation window by navigating Control->Annotation (or simple hit the Ctrl-N hotkey) in the top-level menu bar.

2. Click the “Objects” tab in the Annotation window.

3. Click on the Text button in the “Create New” section. Observe the new entry for the text object appear in the “Annotation objects” window.

4. In the Text section of the Annotation window, enter “carbon dioxide over land” into the text box to the right of “Text”

5. In the Text section of the Annotation window left-click-and-hold the drop down arrow icon next to the text box associated with “Lower left”. Drag the mouse cursor over the new square canvas that appeared. This small window represents the larger rendering window. Place the crosshairs near where you wish your text annotation to appear and release the mouse button.




6. Click on the 3D tab in the *Annotation* window.

7. Remove the Show Axis checkmark by clicking the associated radio box.

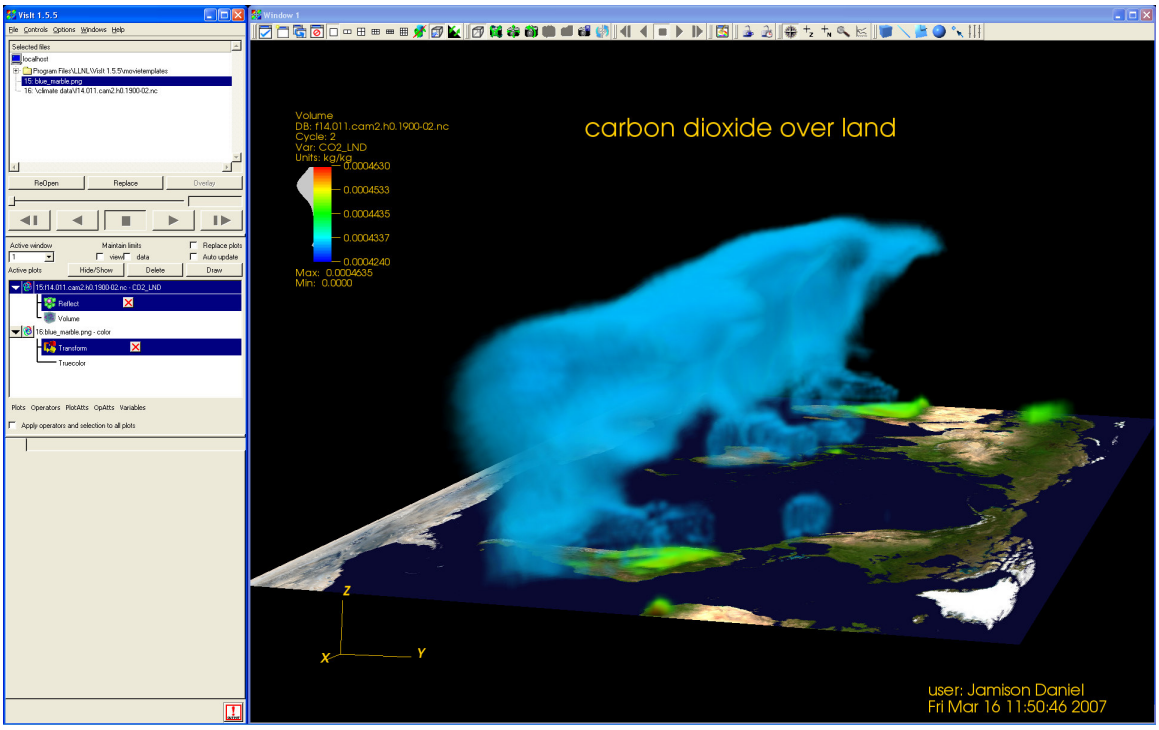
8. Remove the Show bounding box checkmark by clicking the associated radio box.

9. Click the Apply button to update the rendering window.

10. Click the Dismiss button to close the Annotation window.

11. Observe the $CO_2$ plumes rendered in blue and the green $CO_2$ near the Amazon Basin, the Congo, and Eastern Europe in the rendering window.

12. Save your session file.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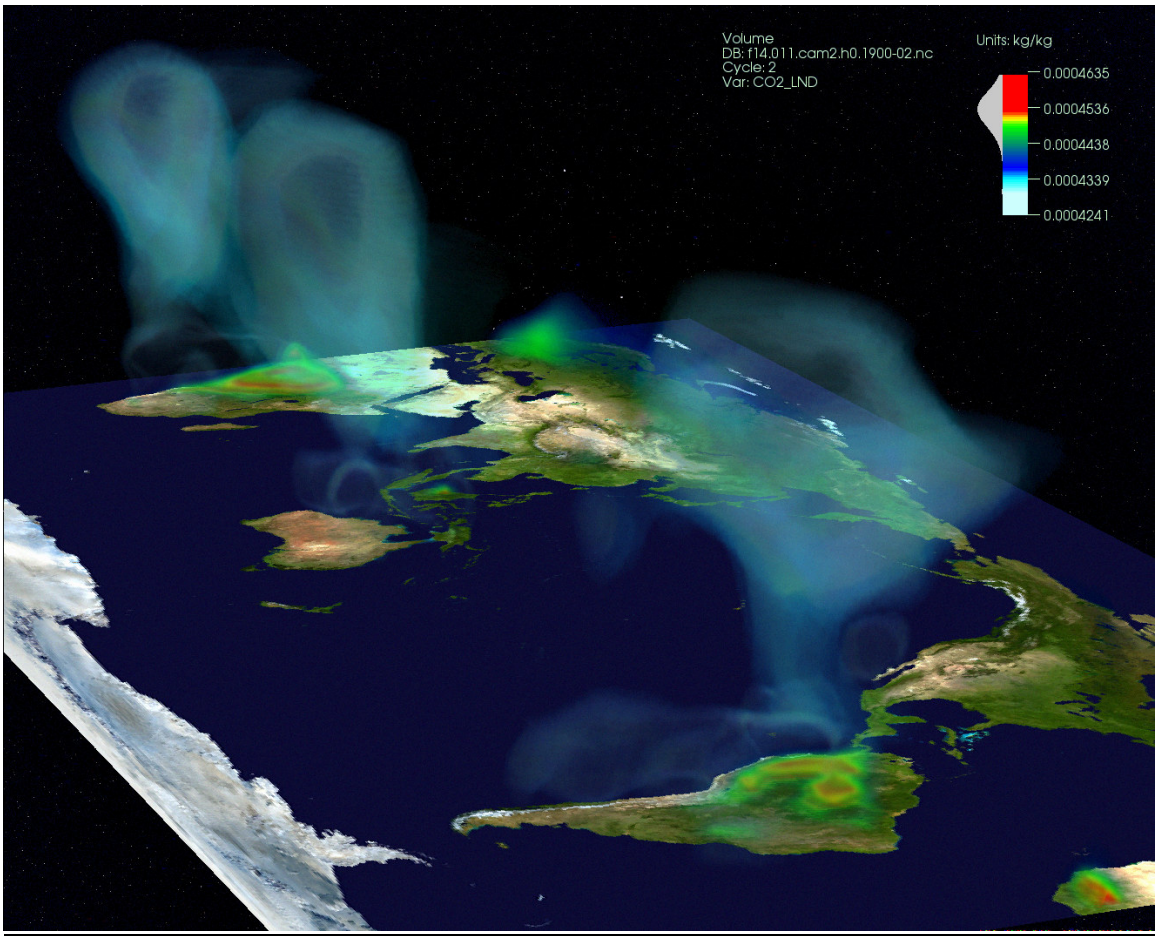
Var: CO2_LND
Units: kg/kg
0.0004630
0.0004533
0.0004435
0.0004337
0.0004240
Max: 0.0004635
Min: 0.0000
carbon dioxide over land
Z
X
Y
user: Jamison Daniel
Fri Mar 16 11:50:46 2007


Volume
DB: f14.011.cam2.h0.1900-02.nc
Cycle: 2
Var: CO2_LND
Units: kg/kg
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0.0004536
0.0004438
0.0004339
0.0004241